

&c., we have

$$\begin{aligned} \nabla \psi(s+0.s) = & -\frac{1}{s} \left\{ \psi(s) - \frac{s-1}{1.2} \Delta 0 \cdot \frac{\psi'(s)}{1} + \left(\frac{s-1.2s-1}{1.2.3} \Delta^2 0^2 - \frac{s-1}{1.2} \cdot s \cdot \Delta 0^2 \right) \cdot \frac{\psi''(s)}{1.2} \right. \\ & - \left(\frac{s-1.2s-1.3s-1}{1.2.3.4} \Delta^3 0^3 - \frac{s-1.2s-1}{1.2.3} \cdot s \Delta^2 0^3 + \frac{s-1}{1.2} \cdot s^2 \cdot \Delta 0^3 \right) \cdot \frac{\psi'''(s)}{1.2.3} \\ & \left. + \&c. \right\}. \quad \dots \dots \dots (36.) \end{aligned}$$

Hence if we put

$$\Psi(s) = 0.s + \psi_1(s).s_{-1} + \psi_2(s).s_{-2} + \dots + \psi_{s-1}(s).s_{-s+1},$$

and denote by $\Psi'(s)$, $\Psi''(s)$, &c. the differential coefficients of $\Psi(s)$, regarding the discontinuous functions s_x, s_{x-1} , &c. as incapable of differentiation, we shall have, finally,

$$\begin{aligned} Y = & -\frac{1}{s} \left\{ \Psi(s) - \frac{s-1}{1.2} \Delta 0 \cdot \frac{\Psi'(s)}{1} + \left\{ \frac{s-1.2s-1}{1.2.3} \Delta^2 0^2 - \frac{s-1}{1.2} \cdot s \cdot \Delta 0^2 \right\} \cdot \frac{\Psi''(s)}{1.2} \right. \\ & - \left\{ \frac{s-1 \dots 3s-1}{1 \dots 4} \Delta^3 0^3 - \frac{s-1.2s-1}{1.2.3} \cdot s \cdot \Delta^2 0^3 + \frac{s-1}{1.2} \cdot s^2 \cdot \Delta 0^3 \right\} \frac{\Psi'''(s)}{1.2.3} \\ & \left. + \&c. \right\} \dots \dots \dots (37.) \end{aligned}$$

(23.) As regards s , in every part of the following investigation it will be regarded as a mere given integer number, so that the coefficients in s will come to be calculated in absolute numbers and need give no further concern. It is otherwise with those in x , which mix themselves up with the x contained in $\phi(x+s-1)$ and its differential coefficients in a way requiring special examination, as functions of an independent variable. Let us therefore consider the term multiplied by $\left(\frac{d}{dx}\right)^n \phi(x+s-1)$ in the development of $\phi(x+s-1-s.0)$. This term will be expressed in ARBOGAST'S notation by

$$\frac{s^n \cdot 0^n}{1.2 \dots n} D^n \phi(x+s-1),$$

and the corresponding term in X will be

$$\frac{s^n}{1.2 \dots n} \cdot D^n \phi(x+s-1) \cdot \frac{1-(1+\Delta)^{-\frac{x}{s}}}{\Delta} 0^n.$$

The development of this in factorials $x, x+s, x+2s$, &c., and functions ϕ, ϕ', ϕ'' , &c., is accomplished in equation (35.), but if we would effect it in powers of x we must proceed as follows:—

Suppose $e=2.7182818$, &c. Then we have

$$\begin{aligned} \frac{1-(1+\Delta)^{-\frac{x}{s}}}{\Delta} 0^n &= \frac{1-e^{-\frac{x}{s} \cdot \log(1+\Delta)}}{\Delta} 0^n \\ &= \frac{x}{1.s} \cdot \frac{\log(1+\Delta)}{\Delta} 0^n - \frac{x^2}{1.2.s^2} \cdot \frac{\{\log(1+\Delta)\}^2}{\Delta} 0^n + \frac{x^3}{1.2.3} \cdot \frac{\{\log(1+\Delta)\}^3}{\Delta} 0^n - \&c. \end{aligned}$$

But by equation (5.),

$$\begin{aligned}\frac{\{\log(1+\Delta)\}^{i+1}}{\Delta} 0^n &= \{\log(1+\Delta)\}^i \cdot \frac{\log(1+\Delta)}{\Delta} 0^n \\ &= n(n-1)\dots(n-i+1) \cdot \frac{\log(1+\Delta)}{\Delta} 0^{n-i},\end{aligned}$$

and therefore the foregoing expression becomes

$$\frac{x}{s} \cdot \frac{\log(1+\Delta)}{\Delta} 0^n - \frac{n}{2} \left(\frac{x}{s}\right)^2 \cdot \frac{\log(1+\Delta)}{\Delta} 0^{n-1} + \frac{n(n-1)}{2.3} \cdot \&c.;$$

or, inverting the order of the terms,

$$\begin{aligned}(-1)^n \cdot \left\{ \frac{1}{n+1} \left(\frac{x}{s}\right)^{n+1} \cdot \frac{\log(1+\Delta)}{\Delta} 0^0 - \left(\frac{x}{s}\right)^n \cdot \frac{\log(1+\Delta)}{\Delta} 0^1 + \right. \\ \left. + \frac{n}{2} \left(\frac{x}{s}\right)^{n-1} \cdot \frac{\log(1+\Delta)}{\Delta} 0^2 - \frac{n(n-1)}{2.3} \left(\frac{x}{s}\right)^{n-2} \cdot \frac{\log(1+\Delta)}{\Delta} 0^3 + \&c. \right\}.\end{aligned}$$

Now if $B_1, B_2, B_3, \&c.$ be the numbers of BERNOULLI in their order (the even values $B_2, B_4, \&c.$ being severally $=0$), we have

$$\frac{\log(1+\Delta)}{\Delta} 0^0 = 1; \quad \frac{\log(1+\Delta)}{\Delta} 0^1 = -\frac{1}{2}; \quad \frac{\log(1+\Delta)}{\Delta} 0^2 = B_1 = \frac{1}{6},$$

and so on. Consequently

$$\begin{aligned}\frac{1-(1+\Delta)^{-\frac{x}{s}}}{\Delta} 0^n &= (-1)^n \cdot \left\{ \frac{1}{n+1} \left(\frac{x}{s}\right)^{n+1} + \frac{1}{2} \left(\frac{x}{s}\right)^n + \frac{n}{2} B_1 \left(\frac{x}{s}\right)^{n-1} + \right. \\ &\quad \left. + \frac{n(n-1)}{2.3} B_2 \left(\frac{x}{s}\right)^{n-2} + \frac{n(n-1)(n-2)}{2.3.4} B_3 \left(\frac{x}{s}\right)^{n-3} + \&c. \right\}, \dots \dots \dots (38.)\end{aligned}$$

the series on the right-hand side being continued to $n+1$ terms. This is in fact no other than EULER'S expression for the sum of the series $1^n + 2^n + 3^n + \&c.$ to a given number of terms represented by $\frac{x}{s}$, only that in the case here under consideration $\frac{x}{s}$ may be any fraction, while EULER'S demonstration of the series in question is essentially confined to $\frac{x}{s} =$ a positive integer.

(24.) If we make $x = -1$, the foregoing expression becomes

$$\begin{aligned}\frac{1-(1+\Delta)^{\frac{1}{s}}}{s} 0^n &= \nabla 0^n = -\frac{1}{n+1} \left(\frac{1}{s}\right)^{n+1} + \frac{1}{2} \left(\frac{1}{s}\right)^n - \frac{n}{2} B_1 \cdot \left(\frac{1}{s}\right)^{n-1} - \frac{n(n-1)}{2.3} B_2 \left(\frac{1}{s}\right)^{n-2} + \&c. \\ &= -\frac{1}{s^{n+1}} \left\{ \frac{1}{n+1} - \frac{1}{2} \cdot s + \frac{n}{2} B_1 \cdot s^2 - \frac{n(n-1)}{2.3} B_2 \cdot s^3 + \&c. \right\} \dots \dots \dots (39.)\end{aligned}$$

continued to $n+1$ terms, inclusive of the vanishing ones having $B_1, B_2, \&c.$ for coefficients.

(25.) Thus the expression for X becomes

[illegible]

$$\begin{aligned}
& + \frac{2x^3 + 3sx^2 + s^2x}{12.s} \phi''(x+s-1) \\
& - \frac{x^4 + 2sx^3 + s^2x^2}{24.s} \phi'''(x+s-1) \\
& + \frac{6x^5 + 15x^4s + 10s^2x^3 + s^4x}{720.s} \phi^{iv}(x+s-1) - \&c.
\end{aligned}$$

$$Y = -\frac{1}{s} \left\{ \Psi(s) - \frac{s-1}{2} \cdot \Psi'(s) + \frac{s^2-3s+2}{12} \cdot \Psi''(s) + \frac{s^2-2s+1}{24} \Psi'''(s) + \right. \\ \left. + \frac{s^4+10s^2-15s+6}{720} \cdot \Psi^{iv}(s) + \&c. \right\} (41.)$$

(26.) We shall now proceed to the more immediate object of this paper, viz. the expression of the number of ways in which a given number x is susceptible of partition, the number of parts being given.

Let s be the number of parts into which x is to be divided, and let ${}^1\Pi(x)$ represent the number of s -partitions of which it is susceptible. It is evident then that if $s=1$ there is but one possible, so that in all cases ${}^1\Pi(x)=1$.

If $s=2$, the partitions stand thus:

$$1, x-1; \quad 2, x-2; \quad 3, x-3; \quad \dots$$

whose number is $\frac{x}{2}$. Therefore we have

$$^3\Pi(x) = \frac{x}{2} = \frac{x}{2} - \frac{1}{2} \cdot 2_{x-1}.$$

If $s=3$, the partitions so grouped as that none shall be twice repeated, will stand as follows :—

1, 1, $x-2$	2, 2, $x-4$	3, 3, $x-6$, &c.
1, 2, $x-3$	2, 3, $x-5$	&c.
1, 3, $x-4$	&c.	
&c.		

The first column will consist of all the possible bipartitions of $x-1$, each associated with 1, and their number is therefore ${}^3\Pi(x-1)$. The second will consist of the bipartitions of $x-2$, exclusive of $(1, x-3)$, each associated with 2. Their number therefore will be identical with the total number of bipartitions of $x-4$, because, so far as the number of cases is concerned, it matters not whether we consider $x-4$ as parted into $(1, x-5)$, $(2, x-6)$, &c., or $x-2$ as parted into $(2, x-4)$, $(3, x-5)$, &c., the reason of which will be obvious on trying any particular case. The number of terms therefore in the second column will be ${}^3\Pi(x-4)$. In like manner that in the third will be ${}^3\Pi(x-7)$, the bipartitions of $x-3$ beginning with $(3, x-6)$, being

identical in number with those of $x-7$, beginning with $(1, x-8)$, and so on. Thus we have

$${}^3\Pi(x) = {}^3\Pi(x-1) + {}^3\Pi(x-4) + {}^3\Pi(x-7) + \&c.$$

Next, with respect to the number of terms to which the right-hand member of this equation is to be continued: it will be that of the columns, which will continue without repetition so long as the number $x-2m$ in the first combination $(m, m, x-2m)$ of any one of them shall be not less than m , or so long as $x-3m$ shall not be negative.

Hence we must have $m = \frac{x}{3}$, since the next greater value of m , viz. $m = \frac{x}{3} + 1$, will give the tripartition $(\frac{x}{3} + 1, \frac{x}{3} + 1, x - 2\frac{x}{3} - 2)$. Now x cannot exceed $3\frac{x}{3}$ by more than 2, so that $x - 2\frac{x}{3} - 2$ cannot exceed $\frac{x}{3}$, and must therefore be less than $\frac{x}{3} + 1$. Hence we conclude that the number of tripartitions is derived from that of bipartitions by the equation

$${}^3\Pi(x) = {}^3\Pi(x-1) + {}^3\Pi(x-4) + \dots + {}^3\Pi(x-7) \dots \text{to } \frac{x}{3} \text{ terms.}$$

(27.) Applying a similar reasoning to the higher cases, we shall find as follows:—

$$\dot{\Pi}(x) = \dot{\Pi}^{s-1}(x-1) + \dot{\Pi}^{s-1}(x-s-1) + \dot{\Pi}^{s-1}(x-2s-1) \dots \text{to } \frac{x}{s} \text{ terms; } \quad (42.)$$

a relation which, with many others of greater generality, has also been arrived at by Mr. WARBURTON.

(28.) Suppose now we set out from the equation ${}^1\Pi(x) = 1$, and proceed to derive from this value those of ${}^2\Pi(x)$, ${}^3\Pi(x)$, &c. in succession. It will be apparent from the course of the foregoing investigations, and from the nature of circulating functions, that the general expression for $\dot{\Pi}(x)$ must consist of two portions, the one non-periodical, a function of x , and which may be represented by $\phi(x)$, the other periodical or circulating, which we may denote by Q_s , so that we shall have in general to consider the following form of $\dot{\Pi}^{s-1}(x)$,

$$\dot{\Pi}^{s-1}(x) = \phi(x) + Q_s,$$

from which to derive the value of $\dot{\Pi}(x)$.

When we substitute this in the general expression (equation 42.), we get

$$\begin{aligned} \dot{\Pi}(x) &= \phi(x-1) + \phi(x-s-1) + \dots (y \text{ terms}) \\ &\quad + Q_{x-1} + Q_{x-s-1} + \dots (y \text{ terms}), \end{aligned}$$

where $y = \frac{x}{s}$. Now with respect to the first portion of this, if $\phi(x)$ in any one case be a rational integral function of x , it will be so in all subsequent cases, as is evident from the course of the preceding investigations. This part of $\dot{\Pi}(x)$ then has been already dealt with, and its complete expression is $X+Y$ of equations (34. 35.), or (38. 39.).

(29.) We have therefore now only to consider the remaining portions, which we shall call Z , viz.

$$Z = Q_{x-1} + Q_{x-2} + \dots y \text{ terms,}$$

Q_x may represent any circulating function. Suppose it to be such that

$$Q_{x-1} = \chi_0(x) \cdot m_x + \chi_1(x) \cdot m_{x-1} + \dots \chi_{m-1}(x) \cdot m_{x-m+1},$$

and let any term of this, as $\chi_i(x) m_{x-i}$ (which for brevity we will write simply $\chi(x) \cdot m_x$, putting $x = x - i$), be separately considered. Let R be the portion of Z which originates from this term. Then

$$R = \chi(x) \cdot m_x + \chi(x-s) \cdot m_{x-s} + \chi(x-2s) \cdot m_{x-2s} \dots (y \text{ terms}).$$

Let $ts = n$ be the first multiple of s , which is also a multiple of m . Then after t terms the value of m_x, m_{x-s} , &c. will recur, and therefore R resolves itself into t separate series, as follows:

$$\begin{aligned} R = & m_x \left\{ \chi(x) + \chi(x-n) + \chi(x-2n) + \dots \left(\frac{y-1}{t} + 1 \right) \text{terms} \right\} \\ & + m_{x-s} \left\{ \chi(x-s) + \chi(x-n-s) + \dots \left(\frac{y-2}{t} + 1 \right) \text{terms} \right\} \\ & + m_{x-2s} \left\{ \chi(x-2s) + \chi(x-n-2s) + \dots \left(\frac{y-3}{t} + 1 \right) \text{terms} \right\} \\ & + \text{\&c. } (t \text{ series}). \end{aligned}$$

Now we have

$$\frac{y}{t} = \frac{y}{t} t_y + \frac{y-1}{t} t_{y-1} + \dots \frac{y-t+1}{t} t_{y-t+1},$$

whence

$$\frac{y-1}{t} = \frac{y-1}{t} t_{y-1} + \frac{y-2}{t} t_{y-2} + \dots \frac{y-t}{t} t_y = \frac{y}{t} - t_y;$$

and similarly,

$$\frac{y-2}{t} = \frac{y-2}{t} t_{y-2} + \frac{y-3}{t} t_{y-3} + \dots \frac{y-t-1}{t} t_{y-1} = \frac{y}{t} - (t_y + t_{y-1}),$$

and so on. But by equation (25.), since $st = n$, we have

$$\frac{y}{t} = \frac{x}{n} - \frac{1}{n} \left\{ 0 \cdot n_x + 1 \cdot n_{x-1} + 2 \cdot n_{x-2} + \dots \overline{n-1} \cdot n_{x-n+1} \right\}.$$

If therefore we put

$$\xi = \frac{x}{n}$$

$$\begin{aligned} p_x &= \frac{1}{n} \left\{ 0 \cdot n_x + 1 \cdot n_{x-1} + \dots \overline{n-1} \cdot n_{x-n+1} \right\} - 1 \\ &= -\frac{1}{n} \left\{ n \cdot n_x + \overline{n-1} \cdot n_{x-1} + \dots 1 \cdot n_{x-n+1} \right\} \end{aligned}$$

$$q'_x = n_x + n_{x-1} + \dots n_{x-s+1}$$

$$q''_x = n_x + n_{x-1} + \dots n_{x-2s+1}$$

$$q'''_x = n_x + n_{x-1} + \dots n_{x-3s+1}, \text{ \&c.,}$$

we shall have

$$1 + \frac{y-1}{t} = \xi - (p_x + q'_x); \quad 1 + \frac{y-2}{t} = \xi - (p_x + q''_x); \text{ \&c.,}$$

and therefore by equation (27.),

$$\begin{aligned} R = & m_x \cdot \frac{1 - (1 + \Delta)^{-\xi + p_x + q'_x}}{\Delta} \chi(x + n + n.0) \\ & + m_{x-s} \cdot \frac{1 - (1 + \Delta)^{-\xi + p_x + q''_x}}{\Delta} \chi(x + n - s + n.0) \\ & + m_{x-2s} \cdot \&c. + \&c., \end{aligned}$$

which resolves itself, by the transformation of equation (9.), into two sets of terms, $R' + R''$, viz.

$$R' = m_x \cdot \frac{1 - (1 + \Delta)^{-\xi}}{\Delta} \chi(x + n + n.0) + m_{x-s} \cdot \frac{1 - (1 + \Delta)^{-\xi}}{\Delta} \chi(x + n - s + n.0) + \&c. \quad (43.)$$

and

$$R'' = m_x \cdot \frac{1 - (1 + \Delta)^{p_x + q'_x}}{\Delta} \chi(n + n.0) + m_{x-s} \cdot \frac{1 - (1 + \Delta)^{p_x + q''_x}}{\Delta} \chi(n - s + n.0) + \&c. \quad (44.)$$

(30.) If, in pursuance of the process followed in the development of Y , we put

$$X(x) = m_x \cdot \chi(x + n) + m_{x-s} \cdot \chi(x + n - s) + \&c. \text{ (} t \text{ terms),}$$

(denoting also by $X_0(x)$, $X_1(x)$ &c., what this expression becomes when for x we put successively x , $x-1$, $x-2$, &c.), we shall have

$$\begin{aligned} R' &= \frac{1 - (1 + \Delta)^{-\frac{x}{n}}}{\Delta} X(x + n.0) \\ &= \frac{1}{n} \left\{ \frac{x}{1} X(x) - \frac{x(x+n)}{1.2} \Delta 0.X'(x) + \left\{ \frac{x(x+n)(x+2n)}{1.2.3} \Delta^2 0^2 - \frac{x(x+n)}{1.2} \cdot n \Delta 0^3 \right\} \cdot \frac{X''(x)}{1.2} - \&c. \right\} \quad (45.) \end{aligned}$$

The whole assemblage of such terms, giving x all its values, from x to $x-m+1$, therefore will constitute a circulating function explicit in x , and which we shall denote by Z' .

As regards R'' , since s and t are given numerically, it constitutes a periodic function with constant coefficients, to obtain which we have only to consider that, supposing any one of the exponents $p_x + q_x$ to be represented by

$$a \cdot n_x + b \cdot n_{x-1} + c \cdot n_{x-2} + \&c.,$$

we shall have by equation (16.),

$$\frac{1 - (1 + \Delta)^{p_x + q'_x}}{\Delta} = \frac{1 - (1 + \Delta)^a}{\Delta} \cdot n_x + \frac{1 - (1 + \Delta)^b}{\Delta} \cdot n_{x-1} + \&c.$$

(31.) In the particular case in which all the functions $\chi_0(x)$, $\chi_1(x)$, &c. are constant, we may consider them as being themselves the coefficients of a periodic function, such that

$$\chi_i = \chi_0 \cdot m_i + \chi_1 \cdot m_{i-1} + \dots + \chi_{m-1} \cdot m_{i-m+1},$$

so that if we should meet with such expressions as χ_m , χ_{m+1} , &c., they are to be taken as equivalent to χ_0 , χ_1 , &c., a mode of regarding a series of arbitrary constants occurring in a certain order which will tend greatly to simplify and add clearness to what follows. Now we have, generally χ_i being constant,

$$\frac{1 - (1 + \Delta)^h}{\Delta} \chi_i = -h \cdot \chi_i.$$

Consequently, the terms R'_i and R''_i of R_i , corresponding to χ_i in the same way as R' and R'' in general to χ , will become

$$\begin{aligned} R'_i &= \{m_x + m_{x-s} + \dots m_{x-ts+s}\} \cdot \frac{x}{n} \cdot \chi_i \\ R''_i &= -\{m_x + m_{x-s} + \dots m_{x-ts+s}\} \cdot p_s \cdot \chi_i \\ &\quad - m_x \{n_x + n_{x-1} + \dots n_{x-s+1}\} \cdot \chi_i \\ &\quad - m_{x-s} \{n_x + n_{x-1} + \dots n_{x-2s+1}\} \cdot \chi_i - \&c., \end{aligned}$$

in which it will be recollected that $z = x - i$.

(32.) Now if v be the greatest common measure of m and s (v being 1, if these numbers be prime to each other), we have

$$m_x + m_{x-s} + \dots m_{x-ts+s} = v_x,$$

and consequently the value of R_i or $R_i + R_i$ becomes

$$\begin{aligned} R_i &= \left(\frac{x}{n} - p_s\right) \cdot \chi_i \cdot v_{x-i} - m_{x-i} \{n_x + \dots n_{x-s+1}\} \cdot \chi_i \\ &\quad - m_{x-s-i} \{n_x + \dots n_{x-2s+1}\} \cdot \chi_i \\ &\quad - \&c. \end{aligned}$$

(33.) Assembling together similar results for $R_0, R_1, \dots R_{m-1}$, we have

$$\begin{aligned} Z &= \{\chi_0 \cdot v_x + \chi_1 \cdot v_{x-1} + \dots \chi_{m-1} \cdot v_{x-m+1}\} \cdot \left(\frac{x}{n} - p_s\right) \\ &\quad - \{n_x + \dots n_{x-s+1}\} \{\chi_0 \cdot m_x + \chi_1 \cdot m_{x-1} + \dots \chi_{m-1} \cdot m_{x-m+1}\} \\ &\quad - \{n_x + \dots n_{x-2s+1}\} \{\chi_0 \cdot m_{x-s} + \chi_1 \cdot m_{x-s-1} + \dots \chi_{m-1} \cdot m_{x-s+1}\} \\ &\quad - \{n_x + \dots n_{x-3s+1}\} \{\chi_0 \cdot m_{x-2s} + \chi_1 \cdot m_{x-2s-1} + \dots \chi_{m-1} \cdot m_{x-2s+1}\} \\ &\quad - \&c. \end{aligned}$$

Now because m and s have v for a common measure, and that $n = ts$ is the first multiple of s , which is also a multiple of m , it follows that $n = \frac{s}{v} \cdot m$, $\frac{s}{v}$ being an integer.

Hence we have by equation (22.),

$$\begin{aligned} m_x &= n_x + n_{x-m} + n_{x-2m} \dots + n_{x-n+m} \\ m_{x-1} &= n_{x-1} + n_{x-m-1} + \dots n_{x-n+m-1} \\ &\&c. = \&c. \end{aligned}$$

Substituting these therefore, and so arranging the terms that n_x shall always stand first, the series within the brackets on the right-hand, in the expression for Z , become respectively

$$\begin{aligned} &\chi_0 \cdot n_x + \chi_1 \cdot n_{x-1} + \dots \chi_{n-1} \cdot n_{x-n+1} \\ &\chi_{m-s} \cdot n_x + \chi_{m-s+1} \cdot n_{x-1} + \dots \chi_{m-s+n-1} \cdot n_{x-n+1} \\ &\chi_{m-2s} \cdot n_x + \chi_{m-2s+1} \cdot n_{x-1} + \dots \chi_{m-2s+n-1} \cdot n_{x-n+1}, \&c., \end{aligned}$$

and therefore

$$X = \frac{1}{6} \left\{ x(x+2) - \frac{x(x+3)}{2} \right\} = \frac{x^2 + x}{12}.$$

For Y we have

$$\Psi(s) = 0.3_s + 1.3_{s-1} + \frac{5}{2}.3_{s-2}$$

$$\Psi'(s) = 0.3_s + \frac{1}{2}.3_{s-1} + 3_{s-2}$$

whence by equation (37.),

$$Y = -\frac{1}{12} \left\{ 2.6_{s-1} + 6.6_{s-2} + 2.6_{s-4} + 6.6_{s-5} \right\}.$$

For Z we have

$$Q_s = -\frac{1}{2}.2_{s-1} \quad Q_{s-1} = -\frac{1}{2}.2_s$$

whence

$$m=2, s=3, ms=6, v=1, \chi_0 = -\frac{1}{2}, \chi_1 = 0$$

and by (45.), (46), (47.),

$$\begin{aligned} Z &= -\frac{x}{12} - \frac{1}{12} \left\{ 6.6_s + 5.6_{s-1} + 4.6_{s-2} + 3.6_{s-3} + 2.6_{s-4} + 1.6_{s-5} \right\} \\ &\quad + \frac{6}{12} \left\{ 6_s + 6_{s-3} \right\} + \frac{6}{12} \left\{ 6_{s-1} + 6_{s-3} + 6_{s-5} \right\} \\ &= -\frac{x}{12} + \frac{1}{12} \left\{ 6_{s-1} + 2.6_{s-2} + 3.6_{s-3} - 2.6_{s-4} + 5.6_{s-5} \right\} \end{aligned}$$

adding all which parts together, we have $X+Y+Z$, or

$$\Pi(x) = \frac{1}{12} \left\{ x^2 - 6_{s-1} - 4.6_{s-2} + 3.6_{s-3} - 4.6_{s-4} - 6_{s-5} \right\}. \quad (50.)$$

(36.) When $s=4$, we have, therefore,

$$\phi(x) = \frac{x^2}{12}, \quad \phi'(x) = \frac{2x}{12}, \quad \phi''(x) = \frac{2}{12}$$

and, therefore, by equation (35.),

$$X = \frac{1}{48} \left\{ x(x+3)^2 - \frac{x(x+4)}{2} \cdot 2(x+3) + \left\{ \frac{x(x+4)(x+8)}{6} \cdot 2 - \frac{x(x+4)}{2} \cdot 4 \right\} \cdot \frac{2}{1.2} \right\} = \frac{x^3 + 3x^2 - x}{144}.$$

For Y we have

$$\psi_1(s) = \frac{(s-1)^2}{12} = \frac{9}{12}; \quad \psi'_1(s) = \frac{2(s-1)}{12} = \frac{6}{12}; \quad \psi''_1(s) = \frac{2}{12}$$

$$\psi_2(s) = \frac{(s-1)^2 + s^2}{12} = \frac{25}{12}; \quad \psi'_2(s) = \frac{2(s-1) + 2s}{12} = \frac{14}{12}; \quad \psi''_2(s) = \frac{4}{12}$$

$$\psi_3(s) = \frac{(s-1)^2 + s^2 + (s+1)^2}{12} = \frac{50}{12}; \quad \psi'_3(s) = \frac{2(s-1) + 2s + 2(s+1)}{12} = \frac{24}{12}; \quad \psi''_3(s) = \frac{6}{12}$$

$$\Psi(s) = \frac{1}{12} \left\{ 0.4_s + 9.4_{s-1} + 25.4_{s-2} + 50.4_{s-3} \right\}$$

$$\Psi'(s) = \frac{1}{12} \left\{ 0.4_s + 6.4_{s-1} + 14.4_{s-2} + 24.4_{s-3} \right\}$$

$$\Psi''(s) = \frac{1}{12} \left\{ 0.4_s + 2.4_{s-1} + 4.4_{s-2} + 6.4_{s-3} \right\},$$

whence by equation (37.),

$$\begin{aligned} Y &= -\frac{1}{48} \left\{ \Psi(s) - \frac{3}{2} \Psi'(s) + \frac{1}{2} \Psi''(s) \right\} \\ &= -\frac{1}{48} \left\{ 0.4_s + 1.4_{s-1} + 6.4_{s-2} + 17.4_{s-3} \right\} \\ &= -\frac{1}{144} \left\{ 0.12_s + 3.12_{s-1} + 18.12_{s-2} + 51.12_{s-3} + 0.12_{s-4} + 3.12_{s-5} + 18.12_{s-6} + \right. \\ &\quad \left. + 51.12_{s-7} + 0.12_{s-8} + 3.12_{s-9} + 18.12_{s-10} + 51.12_{s-11} \right\}. \end{aligned}$$

Lastly, for Z we have

$$\begin{aligned} Q_s &= \left\{ -0.6_s - 1.6_{s-1} - 4.6_{s-2} + 3.6_{s-3} - 4.6_{s-4} - 1.6_{s-5} \right\} \cdot \frac{1}{12} \\ Q_{s-1} &= \left\{ -1.6_s - 0.6_{s-1} - 1.6_{s-2} - 4.6_{s-3} + 3.6_{s-4} - 4.6_{s-5} \right\} \cdot \frac{1}{12}, \end{aligned}$$

consequently

$$m=6, s=4, v=2, t=3, n=st=12$$

$$\chi_0 = -\frac{1}{12}, \chi_1 = 0, \chi_2 = -\frac{1}{12}, \chi_3 = -\frac{4}{12}, \chi_4 = +\frac{3}{12}, \chi_5 = -\frac{4}{12},$$

and therefore, by equation (46.), which gives the value of Z in this case, putting Z' for the first line of Z, Z'' for the second and Z''' for the rest,

$$\begin{aligned} Z' &= \frac{x}{144} \left\{ -1.2_s - 0.2_{s-1} - 1.2_{s-2} - 4.2_{s-3} + 3.2_{s-4} - 4.2_{s-5} \right\} \\ &= \frac{x}{144} \left\{ (-1-1+3).2_s + (0-4-4).2_{s-1} \right\} \\ &= \frac{x}{144} \left\{ 2_s - 8.2_{s-1} \right\} = \frac{x}{144} - \frac{9x}{144} \cdot 2_{s-1} \\ Z'' &= (2_s - 8.2_{s-1}) \cdot \frac{1}{144} \left\{ 12.12_s + 11.12_{s-1} + 10.12_{s-2} + \dots + 1.12_{s-11} \right\}, \end{aligned}$$

which, putting for 2_s and 2_{s-1} their values

$$12_s + 12_{s-2} + 12_{s-4} + \dots + 12_{s-10},$$

and

$$12_{s-1} + 12_{s-3} + \dots + 12_{s-11}$$

becomes

$$\begin{aligned} Z'' &= \frac{1}{144} \left\{ 12.12_s - 88.12_{s-1} + 10.12_{s-2} - 72.12_{s-3} + 8.12_{s-4} - 56.12_{s-5} + 6.12_{s-6} - \right. \\ &\quad \left. - 40.12_{s-7} + 4.12_{s-8} - 24.12_{s-9} + 2.12_{s-10} - 8.12_{s-11} \right\}; \end{aligned}$$

and lastly,

$$\begin{aligned} Z''' &= \frac{1}{12} \left\{ 1.12_s + 0.12_{s-1} + 1.12_{s-2} + 4.12_{s-3} \right\} \\ &\quad + \frac{1}{12} \left\{ 1.12_s + 4.12_{s-1} - 3.12_{s-2} + 4.12_{s-3} + 1.12_{s-4} + 0.12_{s-5} + 1.12_{s-6} + 4.12_{s-7} \right\} \\ &\quad + \frac{1}{12} \left\{ -3.12_s + 4.12_{s-1} + 1.12_{s-2} + 0.12_{s-3} + 1.12_{s-4} + 4.12_{s-5} - 3.12_{s-6} + 4.12_{s-7} \right. \\ &\quad \left. + 1.12_{s-8} + 0.12_{s-9} + 1.12_{s-10} + 4.12_{s-11} \right\} \end{aligned}$$

$$= \frac{12}{144} \left\{ -12_x + 8.12_{x-1} - 1.12_{x-2} + 8.12_{x-3} + 2.12_{x-4} + 4.12_{x-5} - 2.12_{x-6} + 8.12_{x-7} + \right. \\ \left. + 1.12_{x-8} + 0.12_{x-9} + 1.12_{x-10} + 4.12_{x-11} \right\}.$$

And assembling these several portions, $X + Y + (Z' + Z'' + Z''')$, we get

$$\Pi(x) = \frac{1}{144} \left\{ x^3 + 3x^2 - 9x.2_{x-1} \right\} + \frac{1}{144} \left\{ 0.12_x + 5.12_{x-1} - 20.12_{x-2} - 27.12_{x-3} + 32.12_{x-4} \right. \\ \left. - 11.12_{x-5} - 36.12_{x-6} + 5.12_{x-7} + 16.12_{x-8} - 27.12_{x-9} - 4.12_{x-10} - 11.12_{x-11} \right\}. \quad (51.)$$

(37.) Proceeding now to the case where $s=5$, we have

$$\phi(x) = \frac{x^3 + 3x^2}{144}, \quad \phi'(x) = \frac{3x^2 + 6x}{144}, \quad \phi''(x) = \frac{6x + 6}{144}, \quad \phi'''(x) = \frac{6}{144},$$

whence

$$\phi(x+4) = \frac{(x+4)^3 + 3(x+4)^2}{144}, \quad \phi'(x+4) = \frac{3(x+4)^2 + 6(x+4)}{144}, \quad \phi''(x+4) = \frac{6(x+4) + 6}{144}, \quad \phi'''(x+4) = \frac{6}{144},$$

and executing the reductions, arising from the substitution of these in equation (35.), we find

$$X = \frac{x^4 + 10x^3 + 19x^2 - 22x}{2880}.$$

Again for Y we have

$$\psi_1(5) = \phi(4); \quad \psi_2(5) = \phi(4) + \phi(5); \quad \psi_3(5) = \phi(4) + \phi(5) + \phi(6), \text{ \&c.,}$$

whence

$$\psi_1(5) = \frac{112}{144}; \quad \psi_2(5) = \frac{312}{144}; \quad \psi_3(5) = \frac{636}{144}; \quad \psi_4(5) = \frac{1126}{144}$$

$$\psi'_1(5) = \frac{72}{144}; \quad \psi'_2(5) = \frac{177}{144}; \quad \psi'_3(5) = \frac{321}{144}; \quad \psi'_4(5) = \frac{510}{144}$$

$$\psi''_1(5) = \frac{30}{144}; \quad \psi''_2(5) = \frac{66}{144}; \quad \psi''_3(5) = \frac{108}{144}; \quad \psi''_4(5) = \frac{156}{144}$$

$$\psi'''_1(5) = \frac{6}{144}; \quad \psi'''_2(5) = \frac{12}{144}; \quad \psi'''_3(5) = \frac{18}{144}; \quad \psi'''_4(5) = \frac{24}{144}$$

$$\Psi(5) = \frac{1}{144} \left\{ 0.5_x + 112.5_{x-1} + 312.5_{x-2} + 636.5_{x-3} + 1126.5_{x-4} \right\}$$

$$\Psi'(5) = \frac{1}{144} \left\{ 0.5_x + 72.5_{x-1} + 177.5_{x-2} + 321.5_{x-3} + 510.5_{x-4} \right\}$$

$$\Psi''(5) = \frac{1}{144} \left\{ 0.5_x + 30.5_{x-1} + 66.5_{x-2} + 108.5_{x-3} + 156.5_{x-4} \right\}$$

$$\Psi'''(5) = \frac{1}{144} \left\{ 0.5_x + 6.5_{x-1} + 12.5_{x-2} + 18.5_{x-3} + 24.5_{x-4} \right\}$$

$$Y = -\frac{4}{2880} \left\{ \Psi(5) - 2.\Psi'(5) + \Psi''(5) + \frac{2}{3}\Psi'''(5) \right\}$$

$$= -\frac{1}{2880} \left\{ 0.5_x + 8.5_{x-1} + 128.5_{x-2} + 456.5_{x-3} + 1112.5_{x-4} \right\}.$$

(38.) For Z we have

$$Q_x = -\frac{9x}{144} \cdot 2_{x-1} + \frac{1}{144} \left\{ 0 \cdot 12_x + 5 \cdot 12_{x-1} + \dots - 11 \cdot 12_{x-11} \right\}$$

$$Q_{x-1} = -\frac{9(x-1)}{144} \cdot 2_x + \frac{1}{144} \left\{ -11 \cdot 12_x + 0 \cdot 12_{x-1} + 5 \cdot 12_{x-2} \dots - 4 \cdot 12_{x-11} \right\}.$$

It will be convenient to separate this into two parts, viz.

$$Q'_{x-1} = -\frac{9(x-1)}{144} \cdot 2_x,$$

and

$$Q''_{x-1} = \frac{1}{144} \left\{ -11 \cdot 12_x + 0 \cdot 12_{x-1} + \&c. \right\}.$$

First, then, for Q'_{x-1} , proceeding as in article 30, we have

$$z = x, \chi_0(x) = -\frac{9}{144}(x-1); \chi_1(x) = 0.$$

$$X(x) = 2_x \cdot \chi_0(x+10) + 2_{x-1} \chi_0(x+5)$$

$$= -\frac{9}{144} \left\{ (x+9) \cdot 2_x + (x+4) \cdot 2_{x-1} \right\}$$

$$X'(x) = -\frac{9}{144} (2_x + 2_{x-1}) = -\frac{9}{144},$$

whence Z' consisting now of the single term R' ,

$$Z' = -\frac{9}{1440} \left\{ x^2 + x(9 \cdot 2_x + 4 \cdot 2_{x-1}) - \frac{x(x+10)}{2} \right\}$$

$$= -\frac{9}{2880} \left\{ x^2 - 2x + 10x \cdot 2_x \right\}.$$

As regards the other portion of Z , which in this case is R'' , it has for its expression

$$-\frac{9}{144} 2_x \cdot \frac{1 - (1+\Delta)^{p_x+q'_x}}{\Delta} (9+10 \cdot 0) + 2_{x-1} \cdot \frac{1 - (1+\Delta)^{p_{x-1}+q''_{x-1}}}{\Delta} (4+10 \cdot 0).$$

Now, whatever be h and c , we have always

$$\frac{1 - (1+\Delta)^h}{\Delta} (c+10 \cdot 0) = (5-c)h - 5h^2.$$

In this, if we write for h successively $h' = p_x + q'_x$ and $h'' = p_{x-1} + q''_{x-1}$, and for c , 9 and 4, we find

$$Z'' = +\frac{9}{144} \left\{ 2_x (4h' + 5h'^2) - 2_{x-1} (h'' - 5h''^2) \right\}.$$

But since $x=10$ and $s=5$, we have

$$h' = \frac{1}{10} \left\{ 0 \cdot 10_x + 1 \cdot 10_{x-1} + 2 \cdot 10_{x-2} + 3 \cdot 10_{x-3} + 4 \cdot 10_{x-4} - 5 \cdot 10_{x-5} - 4 \cdot 10_{x-6} - 3 \cdot 10_{x-7} - 2 \cdot 10_{x-8} - 1 \cdot 10_{x-9} \right\}$$

$$h'' = \frac{1}{10} \left\{ 0 \cdot 10_x + 1 \cdot 10_{x-1} + 2 \cdot 10_{x-2} + \dots + 9 \cdot 10_{x-9} \right\}.$$

Substituting which in Z'' and employing the property of equation (14.) for the com-

putation of the coefficients, we find

$$Z'' = \frac{9}{2880} \left\{ 2x \{ 0.10x + 9.10_{x-1} + 20.10_{x-2} + 33.10_{x-3} + 48.10_{x-4} - 15.10_{x-5} - 16.10_{x-6} - 15.10_{x-7} - 12.10_{x-8} - 7.10_{x-9} \} \right. \\ \left. + 2x_{-1} \{ 0.10x - 1.10_{x-1} + 0.10_{x-2} + 3.10_{x-3} + 8.10_{x-4} + 15.10_{x-5} + 24.10_{x-6} + 35.10_{x-7} + 48.10_{x-8} + 63.10_{x-9} \} \right\} \\ = \frac{9}{2880} \{ 0.10x - 1.10_{x-1} + 20.10_{x-2} + 3.10_{x-3} + 48.10_{x-4} + 15.10_{x-5} - 16.10_{x-6} + 35.10_{x-7} - 12.10_{x-8} + 63.10_{x-9} \}.$$

(39.) Finally, we have to consider the portion Z''' of Z originating in Q''_{x-1} , in which the values of χ_0 , χ_1 , &c. are given by the equation

$$\chi_i = \frac{1}{144} \{ -11.12_i + 0.12_{i-1} + 5.12_{i-2} - 20.12_{i-3} \dots - 4.12_{i-11} \},$$

the coefficients being those of equation (51.) in their order of circulation. We have also, since in this case $m=12$, $s=5$, and therefore prime to each other, $v=1$, $t=12$, $n=60$. Whence

$$\chi_0.v_x + \chi_1.v_{x-1} + \dots + \chi_{m-1}.v_{x-m+1} = \chi_0 + \chi_1 + \dots + \chi_{m-1} = -\frac{78}{144},$$

and therefore

$$Z''' = -\frac{26x}{2880} - \frac{26}{2880} \{ 60.60_x + 59.60_{x-1} + 58.60_{x-2} + \dots + 1.60_{x-59} \} \\ - \frac{20}{2880} \{ -11.60_x + 0.60_{x-1} + 5.60_{x-2} - 20.60_{x-3} - 27.60_{x-4} \} \\ - \frac{20}{2880} \{ -36.60_x + 5.60_{x-1} + 16.6_{x-2} - 27.60_{x-3} - 4.60_{x-4} - 11.60_{x-5} + 0.60_{x-6} + 5.60_{x-7} - 20.60_{x-8} - 27.60_{x-9} \} \\ - \frac{20}{2880} \{ +5.60_x - 20.60_{x-1} - 27.60_{x-2} \dots - 27.60_{x-14} \} \\ - \frac{20}{2880} \{ +16.60_x - 27.60_{x-1} - 4.60_{x-2} \dots - 27.60_{x-19} \} \\ - \frac{20}{2880} \{ -27.60_x + 32.60_{x-1} - 11.60_{x-2} \dots - 27.60_{x-24} \} \\ - \frac{20}{2880} \{ -4.60_x - 11.60_{x-1} + 0.60_{x-2} \dots - 27.60_{x-29} \} \\ - \frac{20}{2880} \{ -11.60_x - 36.60_{x-1} + 5.60_{x-2} \dots - 27.60_{x-34} \} \\ - \frac{20}{2880} \{ 0.60_x + 5.60_{x-1} - 20.60_{x-2} \dots - 27.60_{x-39} \} \\ - \frac{20}{2880} \{ +5.60_x + 16.60_{x-1} - 27.60_{x-2} \dots - 27.60_{x-44} \} \\ - \frac{20}{2880} \{ -20.60_x - 27.60_{x-1} + 32.60_{x-2} \dots - 27.60_{x-49} \} \\ - \frac{20}{2880} \{ -27.60_x - 4.60_{x-1} - 11.60_{x-2} \dots - 27.60_{x-54} \} \\ - \frac{20}{2880} \{ +32.60_x - 11.60_{x-1} - 36.60_{x-2} \dots - 27.60_{x-59} \}$$

Assembling, finally, the several portions, X , Y , Z' , Z'' , Z''' , of which $\Pi(x)$ consists, and reducing those periodic functions, which have 5 and 10 for their period, to a period of 60, we see

$$\begin{aligned}
\Pi(x) = & \frac{1}{2880} \left\{ x^4 + 10x^3 + 10x^2 - 30x - 90x.2_x \right\} \\
& + \frac{1}{2880} \left\{ 0.60_x + 9.60_{x-1} + 104.60_{x-2} - 387.60_{x-3} - 576.60_{x-4} + 905.60_{x-5} \right. \\
& - 216.60_{x-6} - 351.60_{x-7} - 256.60_{x-8} + 9.60_{x-9} + 360.60_{x-10} - 31.60_{x-11} \\
& - 576.60_{x-12} + 9.60_{x-13} + 104.60_{x-14} + 225.60_{x-15} - 576.60_{x-16} + 329.60_{x-17} \\
& - 216.60_{x-18} - 351.60_{x-19} + 320.60_{x-20} + 9.60_{x-21} - 216.60_{x-22} - 31.60_{x-23} \\
& - 576.60_{x-24} + 585.60_{x-25} + 104.60_{x-26} - 351.60_{x-27} - 576.60_{x-28} + 329.60_{x-29} \\
& + 360.60_{x-30} - 351.60_{x-31} - 256.60_{x-32} + 9.60_{x-33} - 216.60_{x-34} + 545.60_{x-35} \\
& - 576.60_{x-36} + 9.60_{x-37} + 104.60_{x-38} - 351.60_{x-39} + 0.60_{x-40} + 329.60_{x-41} \\
& - 216.60_{x-42} - 351.60_{x-43} - 256.60_{x-44} + 585.60_{x-45} - 216.60_{x-46} - 31.60_{x-47} \\
& - 576.60_{x-48} + 9.60_{x-49} + 680.60_{x-50} - 351.60_{x-51} - 576.60_{x-52} + 329.60_{x-53} \\
& \left. - 216.60_{x-54} + 225.60_{x-55} - 256.60_{x-56} + 9.60_{x-57} - 216.60_{x-58} - 31.60_{x-59} \right\}. \quad (52.)
\end{aligned}$$

(40.) The periodic function $0.60_x + \dots$ &c. may be somewhat simplified by resolving it into the sum of three others, having respectively 10, 20 and 30 for their periods. For on inspecting its coefficients, we find that the differences of any two, distant from each other by 30, are alternately $+360$ and -360 . Now if we suppose, generally, any such function as

$$a_0.60_x + a_1.60_{x-1} + \&c.$$

to be made up of the sum of three others,

$$p_0.30_x + p_1.30_{x-1} + \&c.$$

$$q_0.20_x + q_1.20_{x-1} + \&c.$$

$$r_0.10_x + r_1.10_{x-1} + \&c.,$$

we shall have, supposing i any number of the series 0, 1, 2, ... 9,

$$p_i + q_i + r_i = a_i, \quad p_{i+10} + q_{i+10} + r_i = a_{i+10}, \quad p_{i+20} + q_i + r_i = a_{i+20}$$

$$p_i + q_{i+10} + r_i = a_{i+30}, \quad p_{i+10} + q_i + r_i = a_{i+40}, \quad p_{i+20} + q_{i+10} + r_i = a_{i+50}$$

which give the following equations of condition among the coefficients a ,

$$a_{30+i} - a_i = - (a_{40+i} - a_{10+i}) = a_{50+i} - a_{20+i}$$

And if these be satisfied (as in this case they are), we have only further to establish the following relations between p , q , r , viz.

$$p_i + q_i + r_i = a_i$$

$$p_{i+10} = p_i + (a_{i+10} - a_{i+30}); \quad p_{i+20} = p_i + (a_{i+20} - a_i)$$

$$q_{i+10} = q_i + (a_{i+30} - a_i).$$

Among the sixty coefficients therefore which this assumption places at our disposal, twenty remain arbitrary, and may be put $=0$.

Suppose, for example,

$$q_i = 0, \quad p_{i+20} = 0,$$

which give

$$p_i = a_i - a_{i+30}, \quad p_{i+10} = (a_i - a_{i+30}) + (a_{i+10} - a_{i+20})$$

$$q_{i+10} = a_{i+30} - a_i, \quad r_i = a_{i+20}.$$

These being calculated, the function $0.60_x + 9.60_{x-1} + \&c.$ reduces itself to the following, which seems the simplest form it admits :

$$\begin{aligned} & -320\{30_x - 30_{x-2} + 30_{x-3} - 30_{x-5} + 30_{x-6} - 30_{x-8} + 30_{x-9} + 30_{x-10} - 30_{x-11} + 30_{x-13} \\ & \quad - 30_{x-14} + 30_{x-16} - 30_{x-17} + 30_{x-19}\} \\ & + 360\{20_{x-10} + 20_{x-11} + 20_{x-12} + 20_{x-13} + 20_{x-14} + \dots 20_{x-19}\} \\ & + \{320.10_x + 9.10_{x-1} - 216.10_{x-2} - 31.10_{x-3} - 576.10_{x-4} + 585.10_{x-5} + 104.10_{x-6} \\ & \quad - 351.10_{x-7} - 576.10_{x-8} + 329.10_{x-9} \dots \dots \dots (53.) \end{aligned}$$

(41.) The problem, "In how many ways can a given number be constructed," is reduced by the author of a short but interesting paper in the Cambridge Mathematical Journal, iv. p. 87*, to the integration of the equations of differences

$$u_{x,y} = u_{x-y, x+y} \text{ and } u_{x,y} - u_{x-y, y} = u_{x-1, y-1},$$

which last equation corresponds to the case where it is required to find in how many ways x can be composed of numbers none greater and not all less than y . The analogy of this problem with that here treated is obvious, the function $u_{x,y}$ being in effect identical with that which in the above notation would be expressed by $\Pi(x), y$ corresponding to our s . Accordingly, as far as $y=4$, to which limit only the inquiry is there extended, the results are identical (the mode of expression excepted) with those of our equations (49.), (50.), (51.)†. The method there pursued (by the successive integration of equations of differences) would of course continue to afford similar results, but without some systematic processes of notation, transformation and reduction, such as those delivered in the foregoing pages, would speedily become too complicated to be followed out, though the sort of form which would ultimately be assumed by the result seems to have been clearly apprehended. Observing that in the cases of $y=2, 3, 4$, the results express in fact *the nearest integers* to certain rational fractions, such as $\frac{x^2}{12}$ in the case of $y=3$, $\frac{x^3+3x^2}{2}$ (x even) and $\frac{x^3+3x^2-9x}{2}$ (x odd) when $y=4$, it is suggested that "probably this simple species of description might be continued." This, on examination of the value above given, when y or $s=5$, appears to be the case, but for higher values it will be necessary to enlarge the terms of the description, so as to take in circulating functions of higher orders, and with more complicated coefficients. To make this apparent, suppose $s=6$. Then, without going into the whole calculation (which however would not be materially more complicated than for $s=5$, and would lead, as in that case, to a final period of 60, only not reducible to the sum

* It bears no name, but I have reason to believe it to be the production of Professor DeMORGAN.

† Mr. WARBURTON has also obtained expressions for the number of partitions as far as 4, and his results, *mutatis mutandis*, agree with the above.

of lower periods), it is easy to see, that besides a non-periodic portion of 5 dimensions in x , and a periodic one with 60 constant coefficients, there will also be a circulating portion of the form

$$a_x \cdot 6_x + b_x \cdot 6_{x-1} + \dots f_x \cdot 6_{x-s},$$

whose coefficients may rise to the second dimension in x . In fact, if we execute the calculation of this portion by the foregoing processes, we find for the values of the coefficients

$$a_x = e_x = 0; \quad b_x = d_x = -\frac{4500x^2 + 15750x}{172800}; \quad c_x = \frac{3209x}{172800}.$$

With regard to the constant coefficients of the periodic portion, it is easy to see, from the manner of their formation, that they must all fall very far short, in numerical magnitude, of the half of 172800, so that the whole effect of this periodical part does, in effect, go to adjust the final value to *the nearest integer* of the rational fraction arising from the assemblage of all the terms in x , and a similar reasoning will apply in all cases.

(42.) The number of partitions of which a given number x is susceptible, admitting 0 into them as a component part, is the sum of the number of 1-partitions, bipartitions, tripartitions up to s -partitions. It may therefore be found, by adding together all the values of $\Pi(x)$, from $s=1$ to $s=s$ inclusive. But it may also be obtained by formulæ in all respects similar to those above demonstrated; for if we take $\Pi_s(x)$ to represent this species of partition, we have, if $s=1$, $\Pi_1(x)=1$ as before. For $s=2$ the partitions stand $0, x; 1, x-1; 2, x-2; \dots \left(\frac{x}{2}+1\right)$ terms, that is,

$$\Pi_2(x) = \Pi_1(x) + \Pi_1(x-2) + \dots \left(\frac{x}{2}+1\right) \text{ terms.}$$

Similarly,

$$\Pi_3(x) = \Pi_2(x) + \Pi_2(x-3) + \dots \left(\frac{x}{3}+1\right) \text{ terms,}$$

and so on to

$$\Pi_s(x) = \Pi_{s-1}(x) + \Pi_{s-1}(x-s) + \dots \left(\frac{x}{s}+1\right) \text{ terms,}$$

of which the formulæ of (30.) and (31.), duly applied, give the value

$$\Pi_s(x) = \frac{1-(1+\Delta)^{-\frac{x}{s}}}{\Delta} \Pi_{s-1}(x+s+s.0) + \frac{1-(1+\Delta)^{-q}}{\Delta} \Pi_{s-1}(s+s.0),$$

where

$$q = -\frac{1}{s} \left\{ s-1.s_{s-1} + s-2.s_{s-2} + \dots 1.s_{s-s+1} \right\},$$

which, developed, affords a calculable value of the function in question.

Collingwood, April 17, 1850.

XX. *Experiments on the Section of the Glossopharyngeal and Hypoglossal Nerves of the Frog, and observations of the alterations produced thereby in the Structure of their Primitive Fibres.* By AUGUSTUS WALLER, M.D. Communicated by Professor OWEN, F.R.S.

Received November 22, 1849,—Read February 21, 1850.

THE object of the present observations is to describe certain alterations which take place in the elementary fibres of the nerve after they have been removed from their connection with the brain or spinal marrow.

The following is a brief summary of the opinions and researches of modern physiologists on alterations of the nerve-tubes.

BURDACH* placed a ligature on the sciatic nerve of a frog, and after the lapse of a week found no alteration of the primitive fibres either above or below the ligature.

STEINRUCK† did the same, and states that in three cases the whole nerve was more slender than on the healthy side, and ascribed it to the atrophy of the neurolema.

VALENTIN‡ denies likewise that there is any alteration of the primitive fibres in the lower portion of the nerve.

GUNTHER and SCHÖN§, whose researches are most interesting, state that the primitive fibres being examined towards the end of a week, after division of the nerve when it had lost its irritability, it was perceived that they had no longer the full round appearance of the sound ones. Here and there their contents appeared as if curdled; from eight to fourteen days after section these structural changes became still more evident, and continued to increase until the fibres appeared flat, broken up, entirely losing their transparency, their contents appearing as if disjointed.

NASSE|| states, that five months after section of the sciatic nerve of a frog, the tubes below the section were broken up into granules and small clumps; that all the nerve-tubes were strongly granulated, in some the small granules being united into oval bodies, which appeared to be surrounded by a pale cylindrical membrane, which in some was wanting, owing probably to its disorganization.

Having in a former communication to the Royal Society described the nerves of the papillæ and of the muscular fibre in the frog's tongue in their normal condition,

* Beitrag zur Mikroskopischer Anatomie der Nerven, E. BURDACH. Königsberg, 1837, p. 42.

† De Nervorum Regeneratione. Berolini, 1838, p. 72.

‡ De Functionibus Nervor Cerebral, &c. Lib. iv. 1839, p. 127.

§ MÜLLER's Archiv, 1840, Versuche und Bemerkungen über Regeneration der Nerven, p. 276.

|| Ueber die Veränderungen der Nerven-fasern nach ihrer Durchschneidung, MÜLLER, Arch. 1839, p. 409.

it is my intention at present to describe various alterations, as seen under the microscope, which take place in the structure of the same nerves after their continuity with the brain has been interrupted by section. The innervation of the frog's tongue is, as I have already shown, derived from two pairs of nerves, one arising from the brain, and traversing a foramen in the posterior part of the cranium, accompanied by the pneumogastric nerve. This pair corresponds to the glossopharyngeal in Man. In its course it descends until it reaches the hyoglossus muscle, when it is accompanied by the lingual vessels passing over part of the hyoid bone, and entering the tongue without giving off any branch to the throat. The other pair arises from the anterior part of the spinal marrow, traverses the first cervical foramen, and constitutes the first cervical pair of nerves. Following the example of BURDACH, I regard this pair as corresponding to the hypoglossal in Man, and shall apply that term to it. It takes its course towards the tongue in a similar direction to that of the former pair, giving off several branches to the muscles of the neck and throat, and when it reaches the hyoglossus muscle it is considerably smaller than the glossopharyngeal. After attaining this muscle it runs parallel to the former nerve, passing below the hyoid bone in its transit to the tongue. For a more minute description I must refer to the paper of E. BURDACH, of which a translation has appeared in the *Annales des Sciences Naturelles*.

Division of the Glossopharyngeal Nerve.

That division of these nerves produces some serious lesion is proved by the death of the animal, which generally takes place a few days after the operation. Considering the well-known tenacity of life possessed by these animals this was quite an unexpected result, for which I am unable at present to afford any satisfactory reason. We can only surmise, that besides their gustatory powers, they have others connected with respiration, in regulating the action of the tongue in closing the nares, for forcing the air into the lungs. Whatever may be the true explanation, it is impossible not to regard this result with surprise, when we consider the serious lesions which this animal is capable of undergoing at other points of the frame without loss of life. The usual time which it survives is variable, and depends greatly on the season of the year. If the examination takes place in summer, death frequently ensues on the fifth day; if in winter, not before the twentieth. For the purpose of avoiding this loss of life, I adopt the plan of dividing the glossopharyngeal on one side only of the tongue, and I find that it has the desired effect of preserving the life of the animal, while we can observe the same alterations on the corresponding side, as well as when both nerves are divided. Another advantage found in the division of a single nerve is, that on the uninjured side we have constantly at hand a means of comparison by which we can judge with certainty respecting any alterations that may be produced in the divided nerve. In cases of any doubt, it will always be found of the greatest service to examine at the same time a minute fragment from each side of the tongue.

The first effects of section of a glossopharyngeal nerve at the throat, are decreased

power of moving the tongue, diminished sensibility, generally very slight on the divided side, and symptoms indicative of some disturbance of the nutritive functions. The diminution of motor power is very slight, as is evident by the almost molecular tremor which still exists in any part irritated, and by the capability of retracting the tongue. The loss of sensation, which is also very slight, arises from the section of a few sensitive filaments which are contained in the glossopharyngeal nerve, and are distributed principally about the tubercular extremities. The lesions of nutrition and circulation on the side of the division are very variable and uncertain. Sometimes that half is œdematous, particularly towards the tubercle. Sometimes the papillæ are much injected and congested, while in other cases this side is more pale than the other. In many instances no difference can be detected between the two sides, until the organ has been slightly irritated, when on the divided side the vessels, and especially those of the fungiform papillæ, become congested and of a deeper red than on the other. Some of these differences probably arise from causes independent of the nervous lesion, as the vessels of the tongue which accompany these nerves are doubtless injured in some of the experiments.

During the first two or three days after section, no alteration in the texture and transparency of the tubes of the papillary nerves can be detected. Generally, at the end of the third and fourth day, we detect the first alteration by a slightly turbid or coagulated appearance of the medulla, which no longer appears completely to fill the tubular membrane, which does not appear to be affected. These alterations of the medulla are best seen in a fragment to which a little distilled water has been added to render it more transparent. When examined twenty-four hours after death, the difference between these and the nerves on the healthy side is still more evident. Commencing decomposition on the healthy side causes the nerve-tubes to swell considerably, so as to attain nearly double their ordinary size. On the divided side the disorganized nerve retains nearly the same size and appearance as when fresh. Caustic potash, which dissolves all the tissues except the nerves, renders the altered nerves more transparent, and consequently the morphological changes are less apparent. Nevertheless, by comparative experiments made simultaneously, we may still detect a difference between the nerves of the two sides. In some cases, in about three or four days after section, I have traced the turbid state of the nerve from the fungiform papillæ into branches containing forty or fifty tubes, where it did not appear to terminate, but where the opacity of the nerve prevented my observing it any further. About five or six days after section, the alteration of the nerve-tubes in the papillæ has become much more distinct, by a kind of coagulation or curdling of the medulla into separate particles of various sizes. Sometimes the coagulated particles have an uneven spongy appearance, as if the component parts of the medulla, *i. e.* the white substance and the axis cylinder, were mixed together. Often they appear merely like separated particles of the medulla, such as are frequently effused from the ends of a divided nerve, and present the double contour and the central nucleus cha-

racteristic of the nervous medulla. In some cases the coagulated particles are very uniform in size and appearance, averaging $\frac{1}{7000}$ th of an inch. In others, the limits between the maximum and minimum dimensions are far greater, namely, from $\frac{1}{3500}$ th to $\frac{1}{12,500}$ th of an inch. The diameter of the altered tubes, examined in the ordinary manner in water, is about a fourth smaller than that of the sound ones, and in many instances the tubular cylinders appear wanting, and the medullary particles to have escaped from the cylinder, and to be merely held together by the neurilema which surrounds the whole nerve. After the application of potash, the diameter of the altered and unaltered nerves is as nearly as possible the same. This equalization of the two is produced almost entirely by a decrease in the size of the sound tubes, which swell considerably in water, and afterwards contract by the application of the alkali. It is therefore probable that the difference of size at this stage between the altered and unaltered nerves arises from the former not absorbing so much within them as the latter. Whether this arises from a ruptured state of the membrane or from a chemical change of the medulla, is not evident. After the surrounding tissues have been removed by potash, the tubular membrane offers no signs of rupture, and the medulla appears less disorganized than before the denudation. The disjointed condition of the medulla is greatest towards the extremities. A portion of each nerve-tube is frequently so disorganized as to be carried away among the tissues dissolved by the alkali. The circular rim so frequently presented by the extremity of the tubes is absent. We often observe around the healthy nervous branches, and the papillary nerve in particular, a common sheath or neurilema fitting closely to the nerve. After disorganization has attained this degree, it appears to form a kind of loose pouch around the nerve and separated from it by an interval of $\frac{1}{3000}$ th of an inch. This pouch appears to form the sole investment of the curdled medullary particles, which, as we have stated, previous to the action of the alkali, appear void of any tubular investment. As we ascend towards the brain the disorganization appears to decrease, the coagulated medulla is more apt to assume the oval form, and at some places it presents its double contour apparently unaffected. The effect of decomposition in the unaltered and altered nerve is similar to that in the former stage. In consequence of the above changes the disorganized nerve is more opaque than the unaltered one. In the tubercles some of the ramifications of the tubes belonging to common sensation become disorganized after the section of the corresponding glossopharyngeals. These alterations take place in the same period and in the same manner as in the papillary nerves. With this exception, all the other nerves of the tongue, which comprise those of common sensation and of muscular action, remain unaltered. The muscular fibres of the papillæ are slightly altered at this period; their transverse striæ are not so distinct as on the healthy side, while their longitudinal ones are more so. The fibre itself is usually paler, narrower and more wavy in its course.

The capillaries are either much congested with dark blood, or they are completely empty and scarcely to be detected.

The epithelium and the ciliary filaments are unaltered.

On the seventh, eighth and ninth days the disorganization of the nervous structure continues to progress. In the papillæ the curdled particles of medulla become still more disconnected, and in parts are removed by absorption. The tubular sheath also is ruptured and disorganized near the extremities of the tubes. In the other ramifications of the glossopharyngeal, the medulla becomes more and more disjointed and collected into oval or circular coagulated masses.

On the tenth day and upwards we perceive another morphological state of the medulla. The coagulated particles lose their amorphous structure and assume a granulated texture. The granules, retained together by slight cohesion, are dark by transmitted light, but of a light white colour by reflexion, and average $\frac{1}{20,000}$ th of an inch.

About the twentieth day the medullary particles are completely reduced to a granular state. The condition of the papillary nerve is represented in Plate XXXI. fig. 2, where we find the presence of the nervous element merely indicated by numerous black granules, generally arranged in a row like the beads of a necklace. In their arrangement it is easy to detect the wavy direction characteristic of the nerves. They are still contained in the tubular membrane, which is but very faintly distinguished, probably from the loss of the medulla and from atrophy of its tissue. The resistance of these granular bodies to chemical agents is most remarkable, for they remain unaffected by acids, alkalies and the ethers, which have so great an influence over the nervous medulla. These granules may be detected within the papillary nerves for a considerable period of time. I have seen them apparently unaltered in the papillæ upwards of five months after division of the nerve, reunion not having taken place.

Division of the Hypoglossal Nerve.

When the hypoglossal nerves are divided at their exit from the spine, all movements of the throat and tongue are abolished, and the process of respiration entirely at an end. The tongue may be drawn from the mouth remaining completely inert, pinching or cutting causing no appearance of pain. Hence we may conclude that this nerve is of a mixed nature, containing sensorial as well as motor filaments. Another experiment, which shows this more plainly, consists in dividing one hypoglossal nerve near the spine on one side, and on the other the glossopharyngeal at its exit from the cranium. Pinching and other modes of irritation cause no pain on the side where the hypoglossal is divided, while on the other undoubted pain is caused.

After division of the hypoglossals at the throat, the motor and sensorial powers of the tongue are not entirely lost. When drawn out of the mouth, the extremity only remains fixed between the jaws, flaccid and powerless. At the inner half the fibres are still contractile, on account of their belonging to the hypoglossus, which at its lower half receives a branch from the hypoglossal nerve above the point of section. By this

means, aided also by the mylohyoid muscle, which is left unaffected for the same reason, the inner half of the tongue still enjoys contractile powers.

Respiration is hurried and laboured, and death is the invariable result of division of these nerves, whether made at the spine or at the throat. In summer, the animals died at the end of two or three days.

Division of a single hypoglossal only causes paralysis of the corresponding half of the tongue, complete when the section is near the spine, and imperfect when at the throat. The animals generally survive after the section of one nerve.

The peripheric extremities of the hypoglossal nerves are most easily found at the inferior surface of the tongue. By removing a minute fragment at this region, we can observe, without any further preparation, ramifications of nerves, which are gradually reduced to a network of single tubules on the surface, among the capillary network. At the same time, among the muscular fibres are other ramifications, either crossing them in a transverse direction or running parallel. Like the former, they are reduced to single fibres, running in all directions without forming any free ends. It is at the under surface that the alterations of the hypoglossal must be studied.

During the four first days, after section of the hypoglossal nerve, no change is observed in its structure. On the fifth day the tubes appear more varicose than usual, and the medulla more irregular. About the tenth day the medulla forms disorganized, fusiform masses at intervals, and where the white substance of SCHWANN cannot be detected. These alterations, which are most evident in the single tubules, may be found also in the branches. After twelve or fifteen days many of the single tubules have ceased to be visible, their granular medulla having been removed by absorption. The branches contain masses of amorphous medulla.

We are naturally led to inquire, whether extraneous circumstances have any influence over the removal of the tissue. We find that in the summer-time, when the renewal of the tissues must be considerably more active, in consequence of the increased respiration and activity of the animals experimented upon, that the alteration is more rapid than in winter, when they are in a state of torpor and hybernation.

At present we have restricted our observations to the alterations which take place in the ramifications originating from two trunks, but we cannot suppose that this is a local phenomenon, and that other nerves do not participate in similar alterations, and that the brain itself, composed in great part of tubular fibres, must be excluded. Experiments on other nerves already enable me to affirm that such is not the case, and that they are to be found on other nerves, such as the sciatic, &c., and, moreover, that they are as extensive as the nervous system itself. It is impossible not to anticipate important results from the application of this inquiry to the different nerves of the animal system. But it is particularly with reference to nervous diseases that it will be most desirable to extend these researches. If one conviction impresses itself more firmly on the mind than another, it is that what we term functional diseases of

Fig. 1.



Magnified 400 diam^{ss}

Fig. 2.



Magnified 400 diam^{ss}

Fig. 3.



Magnified 400 diam^{ss}

the nerves are in reality owing to certain organic and physical changes in the tubular fibre, which it will be the province of the microscope to ascertain. If a few days' inactivity of a nervous trunk, such as is produced by ligature or section, is sufficient to cause such disorganization of the medulla, how can we refuse to admit of its being altered in cases of prolonged paralysis?

Kensington, October 27, 1849.

DESCRIPTION OF THE PLATE.

PLATE XXXI.

- Fig. 1. Papillary nerve of frog, six days after ligature.
Fig. 2. Papillary nerve, three weeks after section, with muscular fibres in the interior of the capillary coil at the summit of the fungiform papilla.
Fig. 3. Disorganized muscular nerve, from the inferior surface of the tongue, five days after section. The muscular fibre has been omitted in this drawing.

XXI. *Influence of Physical Agents on the development of the Tadpole of the Triton and the Frog.* By JOHN HIGGINBOTTOM, *Hon. Fellow of the Royal College of Surgeons of England.* Communicated by THOMAS BELL, *Esq., Sec. R.S.*

Received April 6,—Read May 16, 1850.

AN opinion has been generally entertained by physiologists that the tadpole of the Frog, when deprived of *the influence of light*, cannot arrive at its full development, or assume the form of the perfect frog.

I made a series of experiments in different positions and degrees of temperature, but particularly in a rock-cellar thirty feet deep, where no solar light ever entered; this situation was also favourable in point of temperature, being

48° FAHR. from March 11th to May 15th.

50° to 54° FAHR. from May 15th to July 6th, and

55° FAHR. from July 6th to October 31st.

My first experiments were performed on the tadpole of the Triton.

Exp. 1.—I found the tadpole of the *Triton punctatus* more tenacious of life than that of the *Triton cristatus*. I commenced with placing a number of the ova, enveloped in blades of grass in the manner usual with this animal, in three open shallow vessels containing water. One vessel I placed in a room where the mean temperature was 60° FAHR., another in the open air at a mean temperature of 50°, and the remaining one in a deep rock-cellar at 48°.

In the temperature of 60° FAHR. some of the tadpoles escaped from the ova in fourteen days, those at 50° in twenty-one days, and those at 48° in the rock-cellar in twenty-one days.

Although the tadpoles in the cellar at 48° escaped as early as those out of doors, they did not afterwards increase in growth, whilst those in the room at 60° and in the open air at 50° became more developed, the former of these having the anterior extremities in thirty-nine days, the latter in forty-nine days, whilst those in the cellar had no appearance of an extremity at the end of sixty-two days.

Exp. 2.—On the 4th of July I made another experiment with the ova of the Triton in the rock-cellar at its maximum temperature of 55° FAHR. I placed a number of ova in that situation; the tadpoles escaped in due time, but, as in the former experiment, they did not proceed in their development, having no appearance of anterior extremities in 105 days, when they died for want of proper food.

Exp. 3.—On the 11th of August I put twenty-four tadpoles of the Triton in water,

in an earthen vessel enveloped in four or five folds of black calico, so as to exclude the light, the mean temperature of the room being 65° FAHR. I placed the same number under a shed where the mean temperature of the atmosphere was 60°, and a similar number in the deep, dark rock-cellar then at a constant temperature of 55°.

In six days several of the tadpoles in the vessel in the room at 65° and in the open air at 60° were dead, and on examination I found that their branchiæ were absorbed, and their opercula nearly closed, and I concluded that they had died of asphyxia. I now took the precaution to place a stone in the centre of each vessel, so as to allow the tritons to leave the water as they lost their branchiæ. Two days afterwards the top of the stones had a number of tritons upon them in the vessels in the room and in the open air.

All those placed in the rock-cellar retained their branchiæ, not one having left the water, although I had placed stones for that purpose. No more tritons died after the stones had been placed in the vessels, as they afforded them the opportunity of leaving the water when the branchiæ were absorbed.

In about twenty-one days afterwards, during the month of September, two or three had left the water and were on the stones placed in the vessel *in the cellar*, fully proving that the animal came to its full development in the absence of light, though this development was retarded by the low temperature of 55°.

Exp. 4.—On the 25th of August I deprived three tritons, one of an anterior, another of a posterior extremity, and the third of the tail. I put these into a vessel, which I enveloped in five or six folds of black-glazed calico so as to exclude the light, and placed it in a dark part of a room where the maximum temperature was 70° FAHR. As it was then the time of the year when the full-grown tritons leave the water, I placed a quantity of clay and flat stones in the vessel with a little water at the lowest part, in order to allow them to remain in the water or out of it.

In a month the amputated limbs had undergone the reproductive process; in one a miniature posterior extremity furnished with toes had been formed, in another the tail, and in fourteen days later the anterior extremity and the toes of the third were reproduced.

I now began a series of experiments on the Frog (the *Rana Temporaria*); this batrachian being more manageable in regard to food, and arriving at its full development in much less time than the Triton, the former only requiring about ten weeks, the latter about five months.

I commenced my experiments and observations on the Frog in March 1848, ascertaining accurately the influence of air, food, temperature and light, *from the ovum to its full development*.

On the Influence of the Atmospheric Air.

There are three modes of respiration in the tadpole of the Frog:—1st, the Branchial; 2nd, the Pulmonary; 3rd, the Cutaneous.

In the branchial state the body of the tadpole is very small, and at this period they flock to the sides of the vessel in which they are contained close to the edge of the water, nearly exposing the branchiæ to the atmospheric air, the lungs being as yet unemployed.

About a fortnight before the metamorphosis of the tadpole into the frog, its body is very large, and the cutaneous surface for respiration, including the tail, is very considerable; but when the development takes place, the body of the frog is again small, and there is not a sufficient surface for respiration, so that if the animal continues in the water, it becomes asphyxiated. Life then depends more on the pulmonary than the cutaneous respiration.

I found that the tadpole of the Frog soon dies in either aërated or boiled water if excluded from atmospheric air; those in aërated water live the longest; some of them I found at the top of the water, and on examination the lungs were observed to be inflated, whilst those tadpoles in the boiled water sank to the bottom of the vessel. Tadpoles put into boiled water exposed to the atmospheric air live as in aërated water.

2. *On the Influence of Food.*

The food of the tadpole is derived from two sources. The first is the gelatine of the ova, the second the plants growing in the water in which they are deposited.

1848.—On the 11th of March I put some spawn of the frog, newly deposited, into eight shallow earthenware vessels containing water; in four of them I added grass and duck-weed to serve as food for the future tadpoles, in the other four I put none. I observed in all the vessels that the tadpoles, after escaping from the ova, had about an equal growth, as long as any of the jelly-like substance of the ova remained; but after that was consumed, the tadpoles in the vessels where there was no grass were promptly retarded in their growth.

April 17th.—To prove whether the jelly of the ova was food for the young tadpoles, I separated a number from the jelly, putting the tadpoles in one vessel with water, and the jelly in another.

In thirteen days I found the tadpoles had not increased in size, and that some of them were very weak and nearly inanimate. On this day I placed them all with the jelly. In seven days the jelly was consumed, and some of the tadpoles had much increased in size, others of them had died from having been so long and at so early a period deprived of their *first food*.

After the tadpole has finished feeding on the jelly, nothing more is required for food than grass and duck-weed, the grass serving for food, the duck-weed both for food and as a shelter, and also probably yielding its influence as a living vegetable in the water. The grass is sufficient as food to produce the full development of the tadpole, which feeds upon the chlorophyle which adheres to the cells of the plant,

when the plant is in a state of decomposition, leaving the fibrous part. They generally feed on the under part of the plant with the abdomen upwards, owing to the position of the mouth.

I supplied the tadpoles with fresh water every third day, and with grass as often as necessary. In those vessels which were placed in the dark it was necessary to add grass more frequently, on account of the loss of the green colour it sustained in that situation.

I observed they did not feed so well at a low temperature. The life of the tadpole cannot be preserved very long with fresh water and air alone without proper food. I placed a number of tadpoles in eight vessels, of which four were excluded from the light, and four exposed to the light in different degrees of temperature; no food was put in any of the vessels after they had consumed the jelly. On the 11th of May, eight weeks and four days after the deposition of the spawn, the tadpoles remained very small, and the last of them died on that day.

The jelly appears to be quite essential as nutriment to sustain the early life of the tadpole. Had they been deprived of it, they would have died at a much earlier period, as proved by my former experiment*.

3. *On the Influence of Temperature.*

On the 11th of March 1848, I procured four round open earthenware vessels, each containing about three pints of water, and filled them about three parts full. In each I put a small quantity of the spawn of the frog just deposited, and I then placed them in four different degrees of temperature.

The *first* was placed near the ceiling in a shaded part of a room, where the mean temperature was 60° FAHR., six or eight folds of black-glazed calico being tied over it so as to exclude all light.

On the 20th of March (see Plate XXXII.) the tadpoles left the ova; on the 23rd the branchiæ were fully formed; on the 22nd of May the first was fully developed at a much earlier period than others placed in a lower part of the same room, exposed to the light at the mean temperature of 58° FAHR., and also earlier than in the pools.

The *second* was placed at the same time in a situation where the mean temperature was 56°. On the 20th of March, nine days after the deposition of the ova, the embryos were lengthened, indicating the head, body and caudal extremity, and lay in a curved position within the ova. On the 25th some escaped from the ova. On the 28th the branchiæ were fully formed, and on the 6th of April they were absorbed. On the 22nd of May the tadpoles had increased in size. On the 18th of August the first was fully developed.

The *third* vessel was put within a larger one and placed in the open air, on a shaded

* According to Mr. Brande (Philosophical Transactions for 1810), the jelly appears to be an intermediate substance between albumen and gelatine.

side of a house, and entirely covered with wood, so as to exclude all light, the mean temperature being 53° FAHR.

March 20th.—In nine days after the deposition of the ova, the embryos retained their globular form, but considerably increased in size.

On the 25th they had the elongated form within the ova; on the 31st they escaped. On the 4th of April the branchiæ were fully formed, and on the 11th they were absorbed. May 22nd, the tadpoles were increased in size. On the 28th of August the first was fully developed (see Plate XXXII.).

The *fourth* vessel I placed in the rock-cellar. The temperature was uniformly 48° FAHR. from the 11th of March to the 15th of May, 50° to 54° FAHR. from May 15th to July 6th, and 55° FAHR. uniformly from July to October 31st.

March 31st.—The tadpoles escaped from their ova on the same day as in that in the open air, the temperature being in the cellar uniformly 48° FAHR., in the open air 53° mean temperature.

On the 6th of April the branchiæ were formed, and on the 18th they were absorbed. On the 22nd of May the tadpoles were very small, but from that period to the 5th of September they grew much more rapidly. On the 31st of October the first was fully developed.

It will be observed (Plate XXXII.) that when the tadpole in the room was fully developed at the mean temperature of 60° FAHR., those in the open air were small at the mean temperature of 53°, but those in the cellar were smaller still, having been influenced by the low temperature of 48°; from March 11th to May 6th, when the temperature became constantly 55°, they advanced more rapidly in size until their full development.

November 17th.—Soon after this period the temperature in the rock-cellar was from 50° to 54° FAHR. for a month, and during that time there were no more tadpoles fully developed. One of them had three legs only; for upwards of three weeks the fourth leg could be seen distinctly under the skin when the animal moved, but it did not protrude.

All these results are displayed in Plate XXXII., in which the difference of temperature and its effects are registered.

4. *On the Influence of Light.*

With regard to the question of full development of the tadpole of the Frog in the absence of light, I am enabled by the most minute observation to state that it advances in growth equally well in the dark and in the light, and that absence of light has therefore no influence in retarding its development.

I have ascertained this by frequent experiments during the last two years; one experiment was made on an extensive scale.

I had six vessels with tadpoles, three exposed to the light in different degrees of temperature, and three from which the light was excluded.

At the first I was led to think the absence of light was even favourable to development, but I afterwards found that the difference depended on a slight increase of temperature owing to the vessel being covered. This fact is rendered obvious by the Plate, in which the temperature and absence of light are fully illustrated.

Nottingham,
February 5, 1850.

P.S. I made these experiments in 1848; they were repeated in the year 1849 with similar results.

XXII. *On the Temperature of Man within the Tropics.*

By JOHN DAVY, M.D., F.R.S., L. & E., *Inspector-General of Army Hospitals.*

Received February 26,—Read May 2, 1850.

IN a paper on the Temperature of Man, which I had the honour to submit to the Royal Society in 1845, and which was published in the Philosophical Transactions for the same year, I expressed the hope of being able to continue the inquiry in the West Indies, to which I was then about to proceed.

In the present communication I propose to lay before the Society the results of the trials made whilst there, viz. during a period of about three years and a half, exclusive of trifling interruptions, and of one prolonged through several weeks, between June 1847 and October of that year, owing to illness.

In making the trials, the same instrument as that before used was employed, and with like precautions to ensure accuracy, and as then, the subject of the observations was the same individual; also, as then, the pulse and respirations were noticed at the time, and invariably in the sitting posture.

The greater number of the observations were made in Barbados, in a house situated about half a mile from the sea-shore and a few feet only above its level,—where the mean annual temperature of the atmosphere is about 80° FAHR., and the range of temperature throughout the year from about 10° to 18° in the open air.

For the sake of comparison, I shall follow as closely as possible the order observed in my former paper in stating the results.

1. *Of the Variation of Temperature during the twenty-four hours.*

To ascertain this, observations were made commonly three times a day, viz. immediately on rising, about 6 A.M., before taking any food, and before making any exertion, even in dressing, clad merely in a light dress consisting of loose drawers and gown, which in that climate are almost always sufficient for comfort;—next, about 2 P.M., sometimes an hour earlier or later, and generally after occupation, either within doors at home, or at an office a mile and a half distant nearly, to which I went in a carriage,—the occupation being chiefly that of reading or writing, or some other requiring little bodily exertion;—next, the last thing before retiring to rest at night, which was commonly at 10 o'clock, rarely later than 11.

It may be further premised, that the manner of living, as to diet and the time of meals, was much the same as in England,—breakfasting commonly at 9 o'clock, dining about 5, without intermediate luncheon, and drinking tea about 7.

The following Table exhibits the observations made in accordance with the above,

daily, during a period of thirty-six months: in an Appendix, the observations as daily recorded will be given, omitting only those which may be considered abnormal, either owing to bodily ailment, or other cause of a special kind, requiring particular notice:—

	Temperature under the tongue.			Pulse.			Respirations.			Temperature of air of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
1845.												
July	98·2	99	98·2	56	61	60	14·7	15·5	16	78·3	81·5	79·4
August	98	98·7	98·2	53·8	53·6	57·9	15	15·7	15·8	78·7	84	80·3
September ...	98	98·9	98·9	54·3	55	62·1	15·2	15·6	15·6	78·6	84·7	80·5
October	97·9	99	98·8	53·4	56·3	61·3	14·6	15·9	16·8	78	85·4	81
November	98	98·6	98·7	53·3	56·5	61	14·8	15·6	16	78	83·4	79·9
December ...	98	98·6	98·6	53·8	55·2	66	14·4	15·5	15·7	75	81·8	77
1846.												
January	98·2	99	98·7	54·3	58·5	61·7	14·6	15·7	15·6	74·3	82	78·2
February ...	98·1	99·1	98·6	55·1	57·1	59·9	14·3	15·5	15·2	74	83	76·6
April	98·1	98·7	98·6	54	54·5	59·5	14·4	15·6	15·4	77	84	79
May	98·2	98·9	98·9	56·2	55·2	61·4	15	15·8	15·6	78·7	85·8	80
June	98·2	99	98·8	55·1	55·6	59·7	14·6	15·7	15·4	79	84·7	81
July	98·2	99	98·9	54·5	54·5	60·7	14·7	16	15·3	78·8	84·8	81·4
August	98·1	99	98·9	54·2	55·6	60·5	14·6	15·9	15·6	77·7	85·5	81·7
September ...	98	99	98·2	55	54	60·8	14·3	15·9	16	78·7	85·1	81·3
October	98·2	99	99	52	55	61	14·4	15·4	15·3	78·2	85·1	81·2
November ...	98·1	98·9	98·8	56·2	55·4	60·1	14·6	15·8	15·6	77·4	84·4	80
December ...	98·1	98·9	98·9	55·3	55·3	63·5	14·5	15·8	15·8	76	80·5	77·4
1847.												
January	98·1	98·9	98·8	54·8	55·3	60·8	14·4	15·4	15	74·6	81·3	77·3
February ...	98	98·8	98·8	55·5	57·6	61·7	14·2	15·5	15·3	73	81·5	76·3
March	98·1	98·8	98·9	54·8	59·2	62·7	14·5	15·6	15	74·6	83·5	77·1
April	98·1	98·7	98·8	55	56·4	62·3	14·2	15·5	15·6	74·7	82·2	77·1
May	98·1	98·9	98·8	56·6	57·8	61·3	14·5	15·8	15·6	76·7	85	79·2
October	98	99	99	54·7	56	55·7	14·5	15·1	15·7	77·7	84·8	80
November ...	98·1	98·8	98·8	53·3	54·8	59·2	14·5	15·1	15·2	76·7	82·3	79
December ...	98	98·8	98·3	52·9	53·5	58	14·1	14·6	15·3	74·5	81·1	76·9
1848.												
January	98·1	98·9	98·8	54·5	56·8	59·3	14·1	14·9	15·2	74·1	80·5	76·6
February ...	98	98·8	98·8	54·9	57	59·7	14·5	15·1	15·5	73·6	82·1	77·5
March	98	98·9	98·9	54·9	57·6	59·7	14·3	15·5	15·4	75·1	81·9	78·2
April	98	98·9	98·9	54·9	57·7	60·9	14·7	15·2	15·3	74·8	82·9	78·1
May	98·1	99	98·9	55·1	56·2	60·6	14·3	15	15·6	78·2	85·6	80·6
June	98	98·8	99	51	56·1	56·8	14·1	14·8	14·9	77·5	84·7	80·4
July	98	98·3	98·9	53	54·2	59·5	14	14·7	14·8	77·7	84·3	79·4
August	98·1	99·1	99·1	55·4	56·3	59·5	13·9	15	14·7	78·4	85·3	80·9
September ...	98·1	99·1	99·1	54·4	57·3	60·4	14	15	15·2	78·9	86·2	81·7
October	98·2	99·1	99	54·3	55·8	61	14·2	15	15·3	78·9	84·8	80·8
November ...	98·1	99·1	98·6	55·2	57·7	59·2	14·2	15·4	15·4	77	83·5	79
	98·07	98·9	99	54·4	56	60·3	14·4	15·4	15	76·7	83·6	79·8

These results, compared with those obtained in England, show marked differences, as will best appear by presenting them together.

Mean temperature under the tongue in England.			Pulse.			Respirations.			Temperature of room.		
7-8 A.M.	3-4 P.M.	12 P.M.	7-8 A.M.	3-4 P.M.	12 P.M.	7-8 A.M.	3-4 P.M.	12 P.M.	7-8 A.M.	3-4 P.M.	12 P.M.
98·74	98·52	97·92	57·6	55·2	54·7	15·6	15·4	15·2	50·9	54·7	62
In Barbados:—											
6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
98·07	98·9	99	54·4	56	60·3	14·4	15·4	15	76·7	83·6	79

The observations from which these mean results are deduced are so consistent, as may be seen by reference to them in detail in the Appendix, as hardly to admit of doubt in relation to their accuracy.

Probably the low morning temperature of the body within the tropics, as shown above, may be owing principally to three circumstances,—to the depressing or lowering power of sleep,—to the light bed-covering used there, and the free circulation of the air in the room. A sheet and a thin coverlet were the only protection from the air; and the windows mostly being open, the outer air had free access, so that towards morning the temperature of the air of the room did not differ from that of the external air commonly more than two or three degrees. Moreover, the higher temperature observed at night, before going to rest, may have conduced to the lower morning temperature noticed on rising, as the lower temperature at night in England, with the opposite circumstances as to bed-clothing and air of sleeping-room, may have conduced to the higher morning temperature recorded there,—fluctuations these in accordance with well-known physiological laws.

2. *Of the Variation of Temperature during different seasons of the year.*

The following Table, formed from the first, exhibits the mean of the observed temperature during the several months comprised therein, as well as the mean of the indoor temperature.

	Mean temperature under the tongue.	Air of room.		Mean temperature under the tongue.	Air of room.
1845.			1847.		
July	98.43	76.00	January	98.60	77.70
August	98.30	80.60	February ...	98.53	80.26
September ...	98.60	81.20	March	98.60	77.40
October	98.56	81.46	April	98.53	78.00
November ...	98.46	80.56	October	98.66	80.83
December ...	98.40	77.90	November ...	98.56	79.66
1846.			December ...	98.36	77.36
January	98.63	78.16	1848.		
February ...	98.60	77.88	January	98.60	77.06
April	98.46	80.00	February ...	98.53	77.73
May	98.66	81.50	March	98.60	78.40
June	98.66	81.56	April	98.60	78.26
July	98.36	81.00	May	98.66	81.46
August	98.70	81.60	June	98.60	80.86
September ...	98.40	81.36	July	98.36	80.46
October	98.73	81.50	August	98.76	81.56
November ...	98.60	80.60	September ...	98.76	82.26
December ...	98.63	77.96	October	98.76	81.50
			November ...	98.60	79.83
				98.54	79.75

Comparing the temperature under the tongue with that of the air of the room, it will be seen that there is some accordance between them, though not a strict one, as if other circumstances than differences of atmospheric temperature have a marked

effect in modifying the temperature of the body within the tropics, where the variations of atmospheric temperature throughout the year are so inconsiderable—circumstances, for instance, of state of health, kind of life led as to exercise, diet, &c., and quality of atmosphere, as to degree of moisture or dryness, and the direction and force of the winds.

3. *Of the Effect of Active Exercise on the Temperature and of Rest after Exercise.*

On most occasions, when active exercise was taken, especially when on military duty, the dress worn was heavier and warmer than that in common use, to which partly the increase of temperature observed may be justly referred. This remark applies to the majority of the following observations:—

	Tongue.	Pulse.	Respirations.	Air of room.
December 17, 1846, 1 P.M. After attending an inspection of a regiment on parade, exposed to the sun about half an hour	99·3	66	17	82
December 28, 1846, 3 P.M. After returning from office in Barbados, with some difficulty in carriage, the latter part of the road being flooded, a torrent rushing over it, 4·39 inches of rain having fallen between 9 A.M. and 3 ^h 30 ^m P.M.	99·	56	17	75
December 28, 1846, 4 P.M. The last hour sitting lightly clad	98·1	52	16	77
January 5, 1847, 1 P.M. After visiting hospitals	99·3	54	16	82
January 5, 1847, 4 P.M. The last hour sitting lightly clad, reading	98·0	50	14	78
January 6, 1847, 1 P.M. After inspecting an hospital	99·2	54	15	82
January 6, 1847, 4 P.M. Since 1 P.M. chiefly reading, lightly clad	98·2	50	14	81
March 26, 1847, 4 P.M. After inspecting hospitals, &c., occupied several hours, the greater part of the time walking	99·8	70	16	85
March 29, 1847, 6 A.M. After rising, before any exertion	98·4	56	15	68
March 29, 1847, 9 A.M. After a walk of three hours, ascending and descending a hill in the neighbourhood of Port of Spain, Trinidad; perspiring ...	99·1	68	17	79
March 29, 1847, 7 ^h 30 ^m P.M. After a ride of about four hours, most of the way at a quick pace; perspiring	99·6	78	17	80
April 3, 1847, 6 A.M. Just risen	98·2	54	14	73
April 3, 1847, 1 P.M. At the foot of the fall of the Marraca, in Trinidad, approached by a steep ascent through forest, an hour's walk, preceded by a ride at a quick pace of several miles; perspiring, temperature of hand 99°·5; that of the air (81° at the fall) was comparatively low from the evaporation of copious spray	100·	110	20	81
April 3, 1847, 6 ^h 15 ^m P.M. On return from Marraca; the last few miles in an open carriage	98·7	68	16	79
April 10, 1848, 3 ^h 30 ^m P.M. After inspecting the hospital at St. Vincent and riding an hour or two	99·4	62	16	85
April 11, 1848, 3 ^h 30 ^m P.M. After visiting the barracks; perspiring	99·4	78	17	84
July 15, 1848, 1 P.M. After a ride of about an hour from Courland Bay, Tobago	99·6	64	16	83
July 15, 1848, 6 ^h 30 ^m P.M. After visiting barracks, &c.	99·7	64	15	81

These results (many more of the like kind might be given) show how readily, when in health, the temperature of the body rises from active exercise and subsides on rest,—both, very much in the same manner and degree as in a cooler climate; and also, unless the exercise be severe, how the temperature is proportionally more affected than either the pulse or respiration.

4. *Of the Effect of Carriage Exercise on the Temperature.*

The carriage used was a light one adapted to the climate, open behind as well as in front, and well-protected from the sun, except when low, by a deep hood: the rate of going was commonly between six and seven miles an hour; a servant drove.

	Tongue.	Pulse.	Respira- tions.	Air of room.
January 28, 1846, 9 P.M. After coming from Mount Wilton, about 900 feet above the level of the sea	97.9	70	15	73
August 27, 1846, 5 P.M. After a drive of about sixteen miles, going to and returning from Villa Nova, in Barbados, in a cool situation about 700 feet above the level of the sea	97.8	48	14	80
September 3, 1846, 11 P.M. After coming from Villa Nova	97.7	58	16	79
November 18, 1846, 5 P.M. After a drive of about twenty-four miles in the heat of the day, going and returning, and some walking exercise in a low district of Barbados, fasting	98.3	60	16	82
November 18, 1846, 10 P.M. Feeling weary, after dinner, followed by tea... ..	99.1	58	15	79
November 21, 1846, 11 ^h 30 ^m P.M. After coming from Villa Nova	97.7	58	16	79
December 18, 1846, 5 P.M. After coming from Blackman's, situated like Villa Nova, and about the same distance; took a good deal of walking exercise there; the wind high	98.6	70	15	80
December 18, 1846, 9 P.M. Feeling weary, hot and thirsty.....	99.7	80	16	79
February 4, 1847, 12 P.M. After coming from Villa Nova	97.5	58	15	74
April 25, 1847, 10 ^h 30 ^m P.M. After coming from Villa Nova	97.1	54	14	77
June 14, 1848, 10 P.M. After coming from Villa Nova	98.2	58	15	82

Many other instances, of which I have notes, might be adduced to show the effects of carriage exercise in lowering the temperature,—an effect previously observed in England. Those given, which were chiefly at night, were best marked, no doubt owing to the temperature of the air then being lower than by day, and the heat from the reflected and direct rays of the sun being then entirely avoided. When coming from the higher grounds of the interior of Barbados at night, and often when ascending them by day, the feeling of coolness was such as to render agreeable some additional clothing, which was always provided, though the difference of atmospheric temperature was only of a very few degrees. The latter observations, those of the 18th of November 1846 and of the 18th of December, are given as showing the tendency to augmentation of temperature of body in an undue degree after unusual depression, preceded by fatiguing exercise. The rise, so far as it was abnormal, was probably owing to the influence of the fatigue, for it was not witnessed if such exercise had not been taken.

5. *Of the Effect of Gentle Walking Exercise on the Temperature.*

The following observations were made when convalescing from illness (an anthrax with extensive sloughing and general derangement of health), a time when the body in a delicate state seems to be very readily acted on and to show the effects with unusual distinctness:—

	Tongue.	Pulse.	Respira- tions.	Air of room.
March 7, 1847, 6 ^h 15 ^m A.M. Just risen	97·8	52	14	74
March 7, 1847, 3 P.M. During the last two hours taking gentle exercise within doors, making some chemical experiments	98·3	56	15	82
August 17, 1847, 5 ^h 45 ^m A.M. Just risen	97·8	62	15	77
August 17, 1847, 7 ^h 45 ^m A.M. During last half hour walking slowly in shaded gallery, exposed to the wind; feelings agreeable; feet and hands warm	97·8	68	16	80
August 19, 1847, 5 ^h 45 ^m A.M. Just risen	98·6	62	15	79
August 19, 1847, 8 A.M. Last half hour walking in gallery; not exposed to the wind; perspiring gently	98·4	70	17	81
August 21, 1847, 5 ^h 35 ^m A.M. Just risen	98·4	60	15	78
August 21, 1847, 7 ^h 30 ^m A.M. After walking about half an hour; hands and feet glowingly warm	98·2	76	17	81
August 22, 1847, 5 ^h 45 ^m A.M. Just risen	98·5	62	16	79
August 22, 1847, 7 ^h 45 ^m A.M. After walking in gallery about half an hour, very lightly clad, exposed to the wind; hands and feet very warm	98·2	78	17	82

To appreciate the effect of gentle exercise on the temperature, it requires to be mentioned and kept in mind, that had not such exercise been taken, the thermometer would have risen on its second application from 3° to 5° higher than at the first.

The feeling of increased warmth in the hands and feet from gentle exercise has been noticed in three instances. The diffusion of heat to the extremities, owing no doubt to a freer circulation of the warming medium—the blood—may partly account for the cooling effect under the tongue, and probably in the deep-seated parts from the exercise under consideration. The high temperature commonly observed in the extremities within the tropics, is a circumstance very deserving of note. In the daily observations appended, a record is given of the temperature of the hand during two months, noticed three times a day; from which it appears that on an average it was less than that under the tongue by only 1° . For the purpose of ascertaining the heat of the hand, the bulb of the thermometer was placed between the middle of the palm and the ball of the thumb, and so covered was gently pressed.

6. *Of the Effect of Change of the Temperature of the Atmosphere on the Temperature.*

In illustration of this effect, I shall notice only a very few of the observations obtained in the West Indies, corroborative of those collected many years ago in the island of Ceylon.

The situation of Villa Nova has already been mentioned: it was there that most of them were made, that spot being well-fitted for trials of the kind, the temperature there by day rarely exceeding 80° , even at the hottest time, and always below 80° at night, often requiring the closure of the bed-room windows, and occasionally a blanket in addition to the bed-clothes.

	Tongue.	Pulse.	Respira- tions.	Air of room.
November 15, 1847, 6 A.M. Just risen, at Villa Nova	98°	56	15	76
November 15, 1847, 2 P.M.	98·7	50	15	76
November 15, 1847, 9 ^h 30 ^m P.M.	97	58	16	76
November 16, 1847, 6 A.M.	98·4	54	15	76
November 16, 1847, 1 ^h 30 ^m P.M.	98·5	50	16	78
November 16, 1847, 9 ^h 30 ^m P.M. Windows closed; feet and hands agreeably warm	97·8	58	16	76
November 17, 1847, 6 ^h 15 ^m A.M.	98·3	54	14	75
November 17, 1847, 9 ^h 25 ^m . At home, in the neighbourhood of Bridgetown	98·8	54	16	77
November 22, 1847, 1 ^h 30 ^m P.M. At home, variously occupied	99·2	62	16	79
November 22, 1847, 4 P.M. Last hour; sitting reading; raining; feel cold; hand 85°	97·9	48	14	75
December 24, 1847, 6 A.M. At home; just risen	98·1	52	14	74
December 24, 1847, 1 ^h 3 ^m P.M. At home; variously employed	99·1	58	16	80
December 24, 1847, 9 ^h 30 ^m P.M. Villa Nova; arrived there 5 P.M.	97·8	56	14	74
December 25, 1847, 6 ^h 15 ^m A.M. Villa Nova; just risen; slept warm; win- dows closed	98·9	60	14	73
December 25, 1847, 12 A.M. Agreeably cool.....	98·5	54	14	76
December 25, 1847, 5 P.M. A feeling almost of cold.....	98·5	52	14	74
December 25, 1847, 9 ^h 30 ^m P.M.	97·85	52	15	74
December 26, 1847, 6 ^h 15 ^m A.M.	98·5	60	15	73
December 26, 1847, 9 ^h 15 ^m P.M. At home; left Villa Nova at noon	98·7	64	16	80

The observations made at Villa Nova, if compared with those made in England, will be found to approximate, especially as regards the morning and night temperature, and may be adduced in confirmation of the explanation given under Section 1, regarding the contrast of observed temperatures there adverted to.

7. *Of the Effect of Excited and Sustained Attention on the Temperature.*

A few instances may suffice to illustrate this effect, selecting those in which it was most strongly marked; between which and those least notable there is a fine gradation, according to degree of exertion of mind, which it would be difficult to appreciate on account of interfering disturbing circumstances.

	Tongue.	Pulse.	Respira- tions.	Air of room.
December 22, 1846, 3 ^h 30 ^m P.M. After delivering a discourse in public, in a well-aired room, lasting about an hour	°			°
December 22, 1846, 5 ^h 20 ^m P.M.	99·8	78	16	82
December 22, 1847, 6 A.M. Just risen	98·9	58	15	80
December 22, 1847, 6 A.M. Just risen	98·1	52	13	75
December 22, 1847, 3 ^h 15 ^m P.M. After delivering a discourse in the same place as the preceding and of about the same length	100·3	90	15	82
December 22, 1847, 9 ^h 30 ^m P.M.	98·9	66	15	77
December 23, 1847, 6 A.M.	97·9	54	14	75
June 24, 1848, 3 ^h 30 ^m P.M. After occupation similar to that last mentioned, and in the same place	99·9	82	15	81
August 30, 1848, 2 P.M. After delivering a chemical lecture in a close and crowded room	100·1	84	15	88
August 30, 1848, 9 P.M.	99·4	62	14	82
August 31, 1848, 6 A.M.	98·2	58	14	80
September 6, 1848, 2 P.M. Similarly occupied; the heat of the room greater; immediately after the pulse was 100	100·4	80	16	88
September 6, 1848, 9 P.M.	99·2	64	15	81
September 7, 1848, 5 ^h 45 ^m A.M.	98·2	54	14	78

The additional observations—those made some hours after the exertion—are given as illustrating an important fact, viz. the rapid manner in which, when the body is free from disease, the functions on rest return to their ordinary state; whilst, on the contrary, when disease is present, especially of an organic kind, even though latent in relation to the most obvious class of symptoms, indications of it may be obtained by attention to the temperature, pulse and respiration; and often, as in instances of pulmonary disease, in a very remarkable and decided manner.

8. *On the Effect of Cool and Well-ventilated Rooms, and of Close and Heated Rooms on the Temperature.*

As regards ventilation, and consequently coolness where there is a concourse of people, the cathedral church of Barbados, and HARRISON'S school-room adjoining, in which lectures were given on the opening of the "REID School of Practical Chemistry," may be mentioned as good and bad examples. In illustration of the effects of each, I shall give a few observations on temperature, noted down when made, which was within about half an hour after quitting the church and the school, conveyed in a carriage, attending in the one divine service, in the other a lecture. The temperature of the air marked, as usual, was that of my sitting-room, which was cooler by several degrees than the school-room, but less cool commonly than the church.

	Tongue.	Pulse.	Respira- tions.	Air of room.
February 28, 1847, 1 P.M. Just come from church	98.4	54	16	83
March 7, 1847, 1 P.M. Just come from church	98.5	54	15	84
March 5, 1848, 2 ^h 45 ^m P.M. Just come from church	98.5	56	15	82
August 2, 1848, 2 ^h 30 ^m P.M. Just come from school-room	99.8	66	13	85
August 9, 1848, 2 P.M. Just come from school-room	99.8	60	16	82
August 16, 1848, 2 ^h 30 ^m P.M. Just come from school-room	99.9	64	16	87
October 18, 1848, 3 ^h 30 ^m P.M. Room less crowded	99.5	58	15	82
October 25, 1848, 5 ^h 15 ^m P.M. Room less crowded	99.4	62	15	83

9. *On the Effect of taking Food and Wine on the Temperature.*

The effect of a meal in moderation, whether the light one of breakfast or the fuller and heavier one of dinner, was to raise the temperature; and this also when wine was sparingly used at the latter, viz. to the extent of two or three glasses; but when more freely drunk, as it commonly is in company, then often its influence on temperature appeared to be depressing. I shall give a few instances in illustration:—

	Tongue.	Pulse.	Respira- tions.	Air of room.
December 21, 1846, 10 P.M. Dinner at 6; wine chiefly champagne and Madeira; no headache; no malaise	°			°
February 6, 1847, 10 P.M. Dinner at 7; the wines similar	98.1	70	15	77
February 13, 1848, 11 ^h 30 ^m P.M. Dinner at 6; about seven miles distant in the country, from whence just returned; kind of wine not noticed	97.8	70	15	71
March 9, 1848, 10 ^h 30 ^m P.M. Dinner at 7; kind of wine not noted down ...	97.3	64	16	78
May 29, 1848, 12 P.M. Dinner at 7; wines chiefly champagne and claret ...	97.9	64	15	77
August 9, 1848, 11 P.M. Dinner at 7; the wines like the last	98	72	16	79
	98	70	15	79

	Mean Temp ^{re} 60. ^o Fahr.	Mean Temp ^{re} 56. ^o Fahr.	Mean Temp ^{re} 53. ^o Fahr.	Mean Temp ^{re} 51. ^o Fahr.
1848.				
March 11. th				
20. th				
23. rd				
25. th				
27. th				
28. th				
31. st				
April 4. th				
6. th				
10. th				
May 22. nd				
Aug ^t 18. th				
28. th				
Oct ^r 31. st				

John Higinbottom, del.

J. Basire, lith.

It is deserving of remark, that whenever wine was used, except in great moderation, though never to the excess of an inebriating effect, on the following morning the temperature under the tongue was found to be more or less above the average, and the pulse commonly quicker than usual. It is also worthy of remark, that occasionally the effect at night was to increase the temperature of the body, and that in a marked manner; but whether from some peculiar quality of the wine used, or from some deranged state of the system or other adventitious circumstance, I have not been able to determine.

10. *Of the Effect of Sea-sickness on the Temperature.*

During a voyage from Barbados to St. Christopher, and from thence to Barbados in May and June 1848, in a transport, stopping at some of the intermediate islands, an opportunity offered of making some observations on the effect of sea-sickness, from which I suffered more or less on the several days noticed in the subjoined Table. The degree of sickness, often amounting to vomiting, was such as to render rising disagreeable. Little food was taken on those days, excepting chicken broth with some bread; no wine was drunk. The observations were made in the sitting posture in bed in a well-ventilated cabin.

	Temperature under the tongue.			Pulse.			Respirations.			Temperature of cabin.		
	6-7 A.M.	12-2 P.M.	6-10 P.M.	6-7 A.M.	12-2 P.M.	6-10 P.M.	6-7 A.M.	12-2 P.M.	6-10 P.M.	6-7 A.M.	12-2 P.M.	6-10 P.M.
May 14.	98·7	98·9	.....	58	68	...	16	16	...	81	83	°
15.	98·8	.....	.....	60	...	...	14	...	...	80	...	...
18.	98·2	98·6	.....	54	64	...	14	15	...	80	81	...
26.	98·7	.....	.....	60	...	...	15	...	...	79	...	...
27.	98·8	.....	.....	60	...	...	15	...	...	79	...	...
31.	.....	98·7	99·1	...	58	58	...	15	14	...	82	82
June 1.	98·6	98·8	99·3	58	56	58	14	15	15	81	83	83
2.	98·7	98·3	.....	56	58	...	14	14	...	81	80	...
3.	98·7	99·2	99·4	58	56	60	15	16	15	80	82	82
4.	98·7	.....	.....	58	...	...	14	...	...	80	...	...
	98·65	98·75	99·23	57·55	60·28	58·66	14·44	15·14	14·66	80·24	81·71	82·33

It appears from these few observations, that under the influence of sea-sickness, the morning temperature was higher than ordinary and the pulse somewhat quicker; when the former was lowest, as on the 18th of May, then the vessel being in smooth water, there was scarcely any uneasiness experienced. Comparing the several observations, perhaps the inference may be justifiable, that the tendency of sea-sickness, when not in its severest form, is of an equalizing kind in relation to the temperature, pulse and respiration,—a tendency no doubt promoted by the little variation to which the sea atmosphere is liable, especially within the tropics. On so obscure a subject, however, as sea-sickness, this remark is offered with some hesitation.

11. *Of the Temperature at Sea, when not under the influence of Sea-sickness.*

In returning from the West Indies in the well-appointed steam-packet Clyde, I availed myself of the opportunity to continue the observations on temperature. The results are given in the following Table, commencing on the day after leaving St. Thomas, when all feeling of sea-sickness had ceased, and ending on the 2nd of December, the day before coming in sight of the coast of England. The weather during the greater part of the voyage was favourable: after leaving Fayal, on the 27th of November, it was more or less tempestuous; on the 29th and 30th, it was necessary to have the cabin ports closed. The observations were made in a well-ventilated cabin in the sitting posture,—the port commonly open excepting at night. The diet was fuller and more nourishing than that used in the West Indies, the appetite increasing on passing into a cooler climate; rather more wine was used, viz. a pint of sound Bordeaux at dinner; and the clothing was rendered warmer as required by diminution of warmth of atmosphere:—

	Position of ship at noon.		Temperature under the tongue.			Pulse.			Respirations.			Temperature of cabin.		
	Lat. N.	Long. W.	6-7 A.M.	12-2 P.M.	10 P.M.	6-7 A.M.	12-2 P.M.	10 P.M.	6-7 A.M.	12-2 P.M.	10 P.M.	6-7 A.M.	12-2 P.M.	10 P.M.
Nov.														
16.	22° 39'	61° 8'	98·5	98·8	98·9	54	50	60	14	15	16	78	81	78
17.	24 16	58 11	98·2	98·3	98·4	56	54	66	14	16	15	76	77	77
18.	25 39	55 30	98·2	98·7	98·2	56	52	60	14	16	15	75	77	77
19.	27 33	53 13	98·6	99·3	...	52	72	...	14	15	...	77	79	...
20.	29 19	50 45	98·6	98·1	97·7	60	56	60	14	15	15	77	77	77
21.	31 6	48 9	98·5	97·9	97·8	56	50	62	14	15	15	75	75	73
22.	32 53	45 16	98·7	97·7	97·7	54	54	60	14	14	15	71	73	72
23.	34 43	41 18	98·2	98	98·1	54	56	58	15	15	15	71	71	72
24.	36 23	37 21	98·5	98·1	98·6	58	54	60	14	15	15	69	67	67
25.	37 21	33 34	98·3	98·5	...	52	56	...	14	14	...	64	66	...
26.	38 28	30 2	98·5	98·7	...	56	56	...	14	14	...	66	69	...
27.	38 32	28 40	98·3	98·5	97·5	54	54	54	14	15	15	68	67	66
28.	41 2	25 18	98·4	98·7	98·3	52	58	60	14	16	15	66	61	65
29.	43 19	21 32	98·6	99·4	98	56	62	58	14	15	15	65	63	68
30.	44 59	17 13	98·1	98·9	97·3	54	56	54	14	15	14	61	59	64
Dec.														
1.	46 33	12 7	98·4	98·9	97·9	54	60	56	14	14	14	59	59	63
2.	48 33	6 44	98·7	98	97·6	58	62	48	14	15	...	58	57	59

Comparing these results with those obtained in England and in the West Indies, they will be found to accord more with the former than the latter, the morning being on an average higher than those obtained at night. The small range of temperature is also worthy of note, and its decrease with diminution of atmospheric temperature. In those instances in which the variation was greatest, the higher temperature noted down, was in the middle of the day, commonly in connection with active walking exercise just before taken,—and the lower than ordinary at the same period of the day, was, after sitting for an hour or two exposed to the wind on deck.

Conclusions.

The following are some of the conclusions that appear to be either proved or rendered probable by the preceding results, or by those given in the Tables appended,—supposing, as it is believed, that, were the observations extended to many individuals, no material discrepancy would be witnessed.

1. That the average temperature of man within the tropics is a little higher, nearly 1° , than in a temperate climate, such as that of England.

2. That within the tropics, as had before been found in cooler regions, the temperature of the body is almost constantly fluctuating,—varying according to the variety of agencies to which it is subject, some of which are distinct, others obscure.

3. That the order of fluctuation observed there is different from that in a cooler climate, the minimum degree of temperature being commonly early in the morning, after the night's rest, and not at night previous to going to rest.

4. That all exertion, whether of body or mind, except it be very gentle, coming under the designation of passive rather than active exercise, has a heightening effect on the temperature, while the latter, the passive kind, has rather a lowering tendency, especially carriage exercise.

5. That heavy clothing, especially if tight and close, obstructing the admission and circulation of air, tends to raise the temperature unduly, especially under active exercise; and that close, ill-ventilated rooms, especially when crowded, have in a marked manner the same tendency.

6. That when the body is in a healthy state, then on rest after exercise or exposure to any other exciting cause, it rapidly recovers its normal condition as to temperature.

7. That when labouring under disease, however slight, the temperature is abnormally elevated; and that—judging from observations made, but not recorded, in the Tables—its undue degree is some criterion of the intensity of the diseased action.

8. That within the tropics there is comparatively little difference of temperature between the surface of the body, especially the extremities and the internal parts;—and that there the skin is more active in its function of transpiration and the kidneys are less active as secreting organs; with which it may be conjectured is connected a rapid production and desquamation of cuticle, and the absence, in great part or entirely, of lithic acid in the urinary secretion. This latter fact, however, may be explained in a different manner, on the supposition that the acid is not formed in the blood, or if formed, in a greatly diminished quantity.

9. That the effect of wine, unless used in great moderation, is commonly lowering, that is as to temperature, whilst it accelerates the heart's action, followed after a while by an increase of temperature.

10. That the tendency of sea-sickness is to check what may be considered the natural fluctuation of the temperature, and when severe, like disease, to elevate the temperature.

11. That the tendency of a sea voyage, apart from sea-sickness, is to equalize the temperature without elevating it, an equalization that is best witnessed in voyaging in a tropical sea, where the atmospheric temperature is so little variable.

12. That even at sea, with a change of atmospheric temperature, there is a tendency to change of temperature of the body, the average increasing in proceeding towards the tropics, and diminishing in receding from them.

These conclusions obviously admit of application, and that variously in relation to health and disease. It would be unsuitable to the occasion to dwell on this part of the subject; I shall merely remark, that it is a happy circumstance for man, and seems wisely ordered, that fluctuation of temperature should be connected with a healthy state of the system, and probably conducive to it, in whatever manner produced, whether by change of climate, or atmospheric variation, or by exercise, whether of body or mind. The excellent health which the crews of the West Indian steam-packets have, that are in constant transition from heat to cold, is a striking proof of this, and other instances of a like kind, were it necessary, might be adduced in confirmation.

*Lesketh How, Ambleside,
February 14, 1850.*

APPENDIX.

The thermometer used in making the observations contained in these Tables, was compared with a standard one, and was found to require no correction in its scale for the degrees of temperature indicated when placed under the tongue.

	Temperature under the tongue and in hand.						Pulse.			Respirations.			Temp. of air of room.			
	6-7 A.M.		12-2 P.M.		9-11 P.M.		6-7	12-2	9-11	6-7	12-2	9-11	6-7	12-2	9-11	
	Tongue.	Hand.	Tongue.	Hand.	Tongue.	Hand.	A.M.	P.M.	P.M.	A.M.	P.M.	P.M.	A.M.	P.M.	P.M.	
July 1845.	12.	98.7	97.5	99.5	98	98.25	97.5	64	66	62	15	15	16	80	84	82
	13.	98.35	97.5	99.1	98	98.5	98	58	54	64	17	15	16	79	78	80
	14.	98.4	97.5	99.1	98	98.95	98	58	60	70	15	16	17	77	84	80
	15.	98.7	98	99.3	98.5	99.2	98	60	76	76	15	16	16	78	83	80
	18.	98.4	97.25	99.3	98	99.5	98.5	60	64	70	15	16	17	78	83	77
	19.	98.4	97.5	99.2	98	99	97.5	62	62	60	16	16	16	77	83	79
	20.	98.1	97.25	98.6	97.5	98.7	97.25	56	52	52	15	15	16	77	74	79
	21.	98.6	97.5	99	97.5	98.8	97.5	54	64	54	15	15	16	78	83	80
	22.	97.5	96	98.4	97.5	98.3	97	56	56	60	15	16	16	78	81	81
	23.	97.8	97	98.9	97.5	.....	.....	54	60	.....	16	16	.....	79	84	.....
	24.	97.9	96.25	.....	.....	98.4	97	54	.....	54	15	.....	16	79	.....	79
	25.	97.8	97	98.8	97.5	98.3	97.5	50	62	62	15	16	16	78	85	80
	26.	98.1	97.5	99.1	98	98.7	97.25	62	60	54	14	15	16	78	85	81
	27.	98.2	97	98.6	97	98.1	96.5	52	54	54	15	15	15	80	86	79
	28.	98.2	96.5	98.7	97.25	98.4	97.5	54	54	64	15	15	16	78	84	80
	29.	98.2	96.75	.....	.....	98.7	97.5	50	.....	64	14	.....	16	78	.....	80
30.	98.1	96.5	98.9	97.5	98.4	97.5	50	62	50	14	16	50	78	85	79	
31.	98.2	97	99.1	97.7	98.3	.....	56	61	61	15	16	16	79	85	80	
	98.2	97.1	99	97.7	98.2	97.35	56	61	66.5	14.7	15.5	16	78.3	81.5	79.4	
August 1845.	4.	98.4	97	99	97.5	99	97.5	56	64	60	15	16	16	79	83	82
	5.	98	96.5	98.7	97.25	98	96.5	52	52	52	15	15	15	78	85	78
	6.	97.7	97	99.1	97.5	98	97	54	54	60	14	16	16	78	84	79
	7.	98.25	97.5	98.7	97.7	98.7	98	60	54	54	16	16	15	78	85	82
	8.	97.7	96.7	98.3	96.5	98.3	97.5	50	52	60	15	16	16	78	85	81
	9.	98.2	97	98.5	97	98.6	97.5	52	54	62	15	16	16	79	84	80
	10.	93.9	97	98.7	97.5	97.8	96.7	52	58	64	16	16	16	79	85	80
	11.	98.5	97.5	98.8	97	98.5	97.25	60	52	56	16	15	16	80	85	80
	12.	97.8	97	98.9	98	98.9	98	54	54	62	15	15	16	79	87	81
	13.	97.9	97	98.8	97.5	98.3	97.5	54	52	58	14	15	16	78	83	80
	14.	97.7	96.5	99	97.5	98.7	97.5	50	54	56	15	16	16	78	88	80
	15.	97.8	97	98.7	97.75	98.7	97	52	52	54	14	15	16	79	85	81
	16.	97.9	96.5	98.7	97.5	98.7	97.5	52	54	54	15	16	15	79	86	81
	17.	97.9	97	98.4	97.25	98.2	97.3	54	50	62	15	16	15	79	82	80
	18.	98.1	97	98.7	97	98.7	97.5	54	50	60	14	15	16	77	87	82
	19.	98.3	97	98.4	97.5	98.5	97	54	50	60	14	15	15	78	87	82
	20.	98.3	97.5	98.7	97.5	98.8	97.5	52	56	56	15	16	15	78	77	78
	21.	98.2	97	98.5	97	98.4	97.5	56	54	58	15	15	16	78	82	78
	22.	98	97	98.7	97.7	98.6	97.7	52	54	54	15	16	15	78	83	80
	23.	98	97.7	99	98.5	98.5	97.7	52	54	54	15	16	15	78	85	81
	24.	98.2	97.7	99	98	98.6	97.5	52	50	54	15	15	15	77	84	81
	25.	98.1	97	98.7	97.5	98.7	97.5	54	56	56	16	15	16	78	84	77
	27.	97.9	97	98.8	97.5	98.8	97.5	54	52	62	15	16	16	78	86	80
	28.	98.1	97	.....	.....	.....	.....	60	.....	.....	16	.....	.....	78	.....	.....
	30.	98.2	.....	99	.....	98.9	.....	54	58	60	15	16	15	79	86	81
	31.	97.9	.....	98.6	.....	99.2	.....	54	50	60	15	15	16	80	86	82
	98	97	98.7	97.4	98.16	97.4	53.8	53.6	57.9	15	15.7	15.8	78.7	84	80.3	

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
September 1845.	1. 98	98.9	99.3	54	52	66	15	16	15	78	86	81
	2. 98.3	99.3	99.9	60	56	70	14	15	15	79	86	81
	3. 98.1	98.6	99.3	54	50	58	14	16	15	78	82	80
	4. 98.1	99.1	99.1	60	56	66	15	15	16	79	85	80
	5. 98	98.9	98.9	52	54	60	15	16	14	78	85	79
	6. 98	98.3	99.1	46	50	66	14	15	16	79	80	81
	7. 97.95	98.7	99	50	48	64	15	16	16	77	84	80
	8. 98.2	99.1	98.6	54	50	60	15	15	16	77	86	80
	9. 97.9	99.1	99	52	56	62	15	16	16	78	83	80
	10. 98.1	98.9	98.5	54	56	70	15	16	16	78	85	80
	11. 98.6	99	98.4	70	54	52	15	15	16	78	80	80
	12. 97.8	98.9	98.6	52	52	60	15	15	15	78	85	78
	13. 98.1	99.2	99	52	56	62	15	16	16	78	82	80
	14. 97.9	98.6	98.9	52	52	62	15	16	15	78	84	80
	15. 98.1	99	98.7	52	60	54	15	16	16	78	85	82
	16. 98	98.5	98.6	60	60	60	16	16	15	78	85	82
	17. 98.1	98.9	98.8	60	56	58	16	16	15	78	85	81
	18. 98.2	99	99.3	56	60	70	15	15	16	79	87	82
	19. 98.3	99	99.2	56	56	62	14	15	15	79	86	82
	20. 98.4	99.5	99.3	54	58	60	15	16	16	77	86	77
	21. 98.5	98.8	98.9	52	56	58	14	15	15	80	85	82
	22. 98.2	99.4	99.4	52	62	76	15	16	15	79	84	81
	23. 98.3	99.4	99	56	60	68	16	16	16	78	85	81
	24. 98	98.8	98.3	52	52	51	15	16	15	80	86	80
	26. 98.1	98.4	99	52	52	62	15	16	16	77	85	81
	27. 97.9	98.5	98.7	54	58	62	15	16	16	78	85	82
	28. 97.7	98.5	98.7	52	54	58	15	15	16	80	87	81
	29. 97.9	98.9	98.9	52	52	62	15	15	15	78	86	80
	30. 97.9	99.3	99.3	54	58	62	15	15	16	78	86	82
	98	98.9	98.9	54.3	55	62.1	15.2	15.6	15.5	78.6	84.7	80.5
October 1845.	1. 97.6	99.1	98.9	54	54	58	15	14	16	78	86	82
	2. 97.9	99.3	99	54	62	60	15	15	15	78	86	81
	3. 98	99	99	52	54	66	15	16	16	78	87	82
	4. 97.9	98.8	98.7	51	56	62	14	16	16	78	86	80
	5. 98.1	98.6	98.4	56	56	54	14	16	15	79	85	80
	6. 97.9	99.1	98.7	56	66	60	14	15	15	79	84	84
	7. 98.2	.....	98.7	52	.....	64	14	.....	16	80	.....	82
	8. 98.5	98.6	98.8	52	56	56	15	15	16	78	86	82
	9. 97.8	98.6	98.4	53	54	60	15	16	16	77	86	82
	10. 98.2	.....	98.9	54	.....	68	15	.....	16	78	.....	82
	11. 98	98.7	98.9	52	58	56	14	16	16	78	87	82
	12. 97.9	98.7	.....	52	52	.....	15	16	.....	78	86	.....
	13. 98	98.7	98.8	53	56	62	15	16	16	78	87	82
	14. 98	99.1	98.8	52	56	62	14	15	16	77	87	81
	15. 98.1	99	98.9	54	58	56	15	16	16	78	85	80
	16. 98.2	98.8	98.9	54	62	62	15	17	15	79	86	81
	17. 98.2	99.6	99.4	56	58	64	15	16	16	80	87	83
	18. 97.9	98.9	99	52	60	76	14	16	17	80	82	77
	19. 98	99.4	98.8	64	66	56	16	16	15	78	83	79
	20. 98	99.7	98.6	56	62	70	15	16	16	77	84	79
	21. 98	99.5	99	54	60	58	15	17	16	77	84	80
	22. 97.9	98.9	98.8	50	60	60	14	17	17	77	86	82
	23. 98.2	99.1	98.9	56	60	60	15	16	16	79	87	82
	24. 98.1	99	99.4	58	60	62	14	16	16	79	87	82
	25. 97.9	98.9	99.3	56	54	60	15	16	16	78	86	82
	26. 97.9	98.7	98.9	50	60	52	15	16	15	78	84	80
	27. 97.9	99.1	99.1	53	60	60	15	16	15	80	84	80
	28. 97.7	.....	.....	54	.....	.....	15	.....	.....	78	.....	.....
	29.	98.7	99	.....	54	56	.....	16	16	.....	86	81
	30. 97.8	98.7	99	52	58	62	15	17	16	78	85	81
	31. 97.8	98.6	98.7	52	56	60	15	16	16	78	83	81
	97.9	99	98.8	53.4	56.3	61.3	14.6	15.9	16.8	78	85.4	81

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
November 1845.	1. 97.8	98.7	99	54	56	60	15	16	16	78	85	81
	2. 97.8	98.6	98.8	52	56	66	15	16	16	78	85	81
	3. 97.9	98.8	99	52	60	66	15	17	16	79	86	82
	4. 97.8	98.9	98.9	53	58	62	15	16	16	78	86	81
	5. 97.9	99.1	99.1	54	56	64	15	16	16	80	85	82
	6. 98	98.7	98.6	53	56	60	15	16	15	77	83	80
	7. 98	98.7	98.7	54	56	60	15	15	16	78	80	80
	8. 98.1	99.4	99	52	58	68	15	16	15	78	84	81
	9. 98	98.6	98.5	52	54	56	15	15	15	77	83	80
	10. 98.1	98.6	98.8	56	56	64	15	15	16	78	86	81
	11. 98.2	98.8	98.8	56	56	64	14	16	16	79	86	81
	12. 97.8	98.2	98.5	54	52	62	14	15	16	79	79	78
	13. 98.2	98.8	98.5	54	56	58	15	16	16	79	83	81
	14. 98	99.2	98.6	50	60	54	14	15	15	78	82	80
	15. 97.9	98.6	98.2	54	54	58	15	15	16	78	81	79
	16. 98	98.5	98.4	56	56	60	15	15	15	78	84	78
	17. 98	98.5	98.9	52	56	62	15	15	15	78	81	79
	18. 98	98.5	98.7	50	54	58	15	16	16	78	82	79
	19. 98.1	98.9	98.6	54	60	60	15	16	15	77	84	80
	20. 98	99	98.6	54	56	58	15	15	16	77	84	80
	21. 97.9	98.3	98.9	54	54	60	14	16	16	77	84	80
	22. 98	99.2	98.3	54	62	60	14	16	16	79	85	79
	23. 98.5	98.8	98.5	54	56	60	15	15	16	78	85	77
	24. 97.9	99	99.2	50	58	66	14	16	17	77	83	81
	25. 98.4	99.1	98.6	54	58	58	16	17	16	78	85	78
	26. 97.8	98.3	99	52	54	56	15	16	15	77	83	80
	27. 98.5	98.6	99	52	54	62	14	16	16	78	83	80
	28. 98.2	99.2	98.2	56	60	70	15	16	16	78	81	78
	98	98.6	98.7	53.3	56.5	61	14.8	15.6	16	78	83.8	79.9
December 1845.	1. 97.9	98.6	98.4	48	54	58	15	15	16	78	80	77
	2. 97.9	98.4	98.5	52	52	60	14	15	16	77	82	79
	3. 97.8	98.9	98.8	50	56	56	14	16	16	77	81	77
	4. 98.1	98.7	98.5	54	56	60	14	16	16	77	79	79
	5. 97.9	98.4	98.5	52	56	70	15	16	17	77	81	79
	6. 98.1	98.7	98.4	52	56	60	14	15	16	77	81	79
	7. 97.9	98.3	98.2	50	52	76	15	16	17	77	82	77
	8. 98	98.5	.....	64	60	...	14	15	...	75	82	...
	9. 98.4	98.5	98.9	52	56	56	14	15	16	75	83	77
	10. 97.9	98.4	98.8	54	52	60	14	15	15	76	82	78
	11. 97.9	98.9	98.4	56	56	62	14	16	15	75	83	79
	12. 97.8	.....	.....	56	...	...	14	...	...	77	...	...
	13. 97.9	98.4	98.8	54	54	62	15	15	15	97	81	78
	14. 98	98.5	98.6	54	54	56	13	15	16	75	81	78
	15. 97.7	98.3	98.9	50	54	60	14	15	15	70	80	77
	16. 98.2	98.8	98.2	50	54	60	15	16	16	76	82	78
	17. 98.4	98.8	98.6	52	58	66	15	16	16	77	83	78
	18. 97.9	98.6	.....	50	52	...	15	15	...	75	82	...
	19. 98.4	98.8	98.7	58	52	64	15	16	16	73	80	78
	20. 97.8	98.8	.....	52	50	...	15	16	...	74	82	...
	21. 98.1	98.9	98.6	66	56	60	16	16	15	73	80	74
	22. 97.6	98.6	98.5	52	56	60	14	16	16	74	82	77
	23. 97.9	98.6	99	60	54	56	14	16	15	73	82	76
	24. 97.8	98.6	98.6	54	58	56	14	16	15	74	82	78
	25. 98.3	99.2	98.9	52	60	66	15	16	16	74	81	76
	26. 98.1	98.7	99.2	52	56	58	14	14	15	74	80	76
	27. 98.2	99.3	98.4	54	58	60	15	15	16	73	82	75
	28. 98.3	.....	98.6	56	...	70	14	...	15	72	...	75
	29. 98.1	98.4	98.5	52	52	58	14	15	16	72	82	78
	30. 98.3	98.5	98.4	54	58	76	15	16	16	75	82	78
	31. 98.2	98.6	98.6	60	56	66	15	16	17	76	82	76
	98	98.6	98.6	53.8	55.2	66	14.4	15.5	15.7	75	81.3	77

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
January 1846.	1. 98.2	98.5	99.2	54	56	78	15	15	16	72	83	79
	2. 98	.....	.....	52	.....	.....	14	.....	.....	76		
	3. 98.5	99	98.8	56	62	66	15	15	17	74	80	78
	4. 98.1	98.8	98.8	56	56	62	15	16	16	76	82	77
	5. 98.2	99.1	98.5	56	60	76	15	16	15	75	83	78
	6. 98.3	98.9	98.7	54	60	70	15	16	16	72	81.5	78
	7. 98.3	99	98.7	56	60	62	14	16	15	76	81	78
	8. 98.2	98.8	98.5	54	56	62	15	16	16	74	82	77
	9. 98.3	99.3	.....	58	66	.....	15	16	.....	76	82	
	18. 98.2	99.1	98.6	52	60	58	15	16	15	76	84	78
	19. 98.2	98.7	98.9	54	58	60	14	16	15	76	82	79
	20. 98.2	99.1	98.7	54	60	60	14	16	16	76	83	79
	23. 98.3	98.9	98.5	56	60	56	14	15	15	75	83	79
	24. 98.1	98.9	99.2	56	60	60	15	16	15	76	82	79
	25. 98.1	98.7	98.9	50	52	52	14	15	15	75	81	78
	26. 98.2	.....	.....	54	.....	.....	14	.....	.....	75		
	29. 98.3	98.9	.....	52	52	.....	14	16	.....	72	82	
	98.2	99	98.7	54.3	58.5	61.7	14.6	15.7	15.6	74.3	82	78.2
February 1846.	3. 98.3	99.6	98.7	54	62	74	15	16	16	72	82	76
	4. 97.9	98.8	.....	58	54	.....	15	15	.....	73	78	
	5. 98.5	99.1	98.5	60	56	56	14	16	15	74	82	75
	6. 98.3	99.3	98.5	56	58	58	14	16	15	73	81	76
	7. 98.3	99.3	98.8	52	56	66	14	16	16	72	82	76
	8. 98.2	99.3	98.2	52	58	70	14	16	16	72	85	76
	9. 98.3	99.2	98.9	62	62	64	15	15	16	76	85	78
	10. 97.9	99	.....	50	56	.....	14	16	.....	75	82	
	12. 98	98.8	98.8	52	52	50	14	15	15	72	82	75
	13. 98.2	98.6	98.6	52	54	62	14	15	15	73	84	75
	14. 98.3	99.1	98.5	58	56	56	14	16	15	75	84	76
	15. 97.9	.....	98.8	52	.....	60	14	.....	15	75	.....	81
	16. 98	99.3	99.1	52	60	62	14	16	15	75	84	78
	17. 98.1	98.8	98.4	58	58	60	14	15	15	75	83	76
	18. 98.1	99	98.5	56	56	56	15	16	15	75	83	78
	19. 98	99.1	98.6	52	56	60	15	16	15	75	83	78
	20. 98	99.3	98.4	56	60	66	14	15	16	75	85	79
	21. 98.3	99.3	98.8	56	58	70	14	16	16	76	83	78
	22. 98	98.8	99.1	58	56	62	15	15	15	75	85	80
	23. 98.4	99.2	98.8	56	58	56	14	16	14	77	85	78
	98.1	99.1	98.6	55.1	57.1	59.9	14.3	15.5	15.2	74	83	76.6

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
April 1846.	9. 97·8	98·3	98·5	52	54	56	14	15	15	74	79	77
	10. 98·2	98·5	98·6	56	56	52	15	14	15	77	83	78
	11. 98·2	98·8	.....	56	58	.....	14	16	.....	77	84	.....
	12. 98·4	99	98·6	56	54	64	14	16	16	77	85	80
	13. 98·1	99·2	99	54	56	72	15	16	16	78	84	77
	14. 98·1	99·3	98·2	52	58	70	14	16	16	76	83	79
	15. 98·3	98·7	98·5	54	52	62	14	15	15	77	84	79
	16. 97·9	98·8	98·7	56	52	64	14	15	16	77	85	79
	17. 98·1	98·6	98·4	54	52	60	14	15	15	77	84	79
	18. 98·1	99·3	98·5	52	56	58	14	16	15	77	84	80
	19. 98·2	98·6	98·3	56	54	56	14	16	16	77	82	79
	20. 98·2	98·6	98·5	50	52	52	15	15	15	77	83	79
	21. 98·3	98·9	98·8	52	54	58	15	16	15	76	84	79
	22. 98·3	98·9	98·6	56	56	54	15	15	14	75	83	79
	23. 98·3	99·3	.....	52	56	.....	14	15	.....	77	85	.....
	24. 98·3	99·1	98·6	60	54	60	16	16	16	77	86	80
	25. 98·1	99	98·8	52	56	62	14	16	16	78	85	81
	26. 98·3	99·1	98·8	54	54	56	14	17	16	77	85	82
	27. 98·2	99·1	99	52	56	58	14	17	15	79	85	81
	28. 98·2	98·8	.....	54	56	.....	15	16	.....	78	86	.....
	29.	98·9	98·7	.....	50	54	.....	16	15	.....	85	80
	30. 98·1	98·6	98·6	54	50	62	15	15	16	77	82	79
	98·1	98·7	98·6	54	54·5	59·5	14·4	15·6	15·4	77	84	79
May 1846.	1. 98·1	98·5	99	54	54	62	15	16	16	77	82	79
	2. 98·1	99·1	99	54	56	66	14	16	15	76	85	78
	3. 98·4	98·9	99·2	54	56	64	15	16	15	77	85	80
	4. 98·1	99	99	52	56	62	15	16	16	76	85	81
	5. 98·2	99	98·8	56	54	66	15	16	16	77	84	81
	6. 98·1	98·9	.....	52	54	.....	15	15	.....	77	86	.....
	7. 98·3	99	98·5	60	56	72	16	16	16	79	86	81
	8. 98·2	98·8	98·7	56	56	58	15	16	16	78	86	80
	9. 98·2	98·8	.....	56	56	.....	15	16	.....	79	86	.....
	10. 98·1	99·1	99·3	54	56	60	15	16	16	79	86	81
	11. 98·1	98·9	99·1	56	56	64	15	17	16	78	86	81
	12. 98·4	99·1	98·7	54	56	58	15	16	16	79	86	82
	13. 98·1	98·5	98·4	54	48	54	15	16	15	78	84	81
	14. 98·6	99·1	98·9	54	60	60	15	16	16	78	86	81
	15. 98·3	98·9	98·4	52	54	80	14	15	16	78	86	81
	16. 98·1	99·1	98	56	58	60	16	16	16	79	87	82
	17. 98·3	98·9	98·1	62	54	72	14	17	16	80	88	81
	18. 98	99·2	98·6	70	56	56	14	16	16	77	88	82
	19. 98·1	98·7	98·9	54	54	60	15	16	16	80	87	82
	20. 98·1	.....	.....	56	.....	.....	14	.....	.....	79	.....	.....
	21. 98·2	99	98·4	54	58	54	15	16	15	80	87	81
	22. 98·4	98·7	98·8	54	50	58	15	16	16	79	88	77
	23. 98·4	99·1	98·7	60	56	70	15	16	16	81	87	82
	24. 98·2	99	98·5	58	56	56	15	16	15	79	88	82
	25. 98·2	99·1	.....	56	56	.....	14	16	.....	79	88	.....
	26. 98·3	98·6	98·5	60	52	58	15	15	15	79	79	81
	27. 98·4	99·1	98·7	56	56	56	14	14	15	80	82	82
	28. 98·3	99	99	56	56	60	15	16	14	81	86	84
	29. 98·4	99·4	98·8	60	60	60	15	16	16	82	88	83
	30. 98·5	99·3	99·3	56	56	62	15	16	16	80	87	83
	31. 98·2	99	99	54	52	58	15	15	16	80	85	76
	98·2	98·9	98·8	56·1	55·2	62	15	15·8	15·6	78·7	85·8	80

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
June 1846.	1. 98.3	99.5	99.2	52	56	62	14	16	16	79	87	83
	3. 98.4	99.4	98.9	58	58	56	15	15	15	80	88	83
	4. 98.2	99.5	98.7	58	68	64	15	17	16	82	88	82
	7. 98.2	98.7	98.9	60	54	70	15	15	16	78	82	82
	8. 98.4	99.1	98.7	54	58	60	15	15	16	79	86	81
	9. 98.4	99	98.8	54	54	60	15	16	15	79	86	81
	10. 98.3	98.9	98.7	50	56	58	14	16	16	79	84	79
	11. 98.2	.....	.....	56	.....	.....	15	.....	.....	78	.....	.....
	12. 98.5	99	98.6	58	54	80	16	14	17	79	86	82
	13. 98.4	98.9	98.7	66	56	60	14	16	15	80	85	82
	14. 98.4	98.5	.....	58	52	.....	15	15	.....	80	87	.....
	15. 98	98.7	98.9	52	50	58	14	16	16	80	85	82
	16. 98.2	99.1	98.7	52	56	56	14	16	16	79	82	80
	17. 98.4	99	98.7	58	58	56	15	16	14	79	85	81
	18. 98.1	98.7	.....	52	52	.....	15	16	.....	77	81	.....
	20. 98.1	.....	.....	56	.....	.....	15	.....	.....	79	.....	.....
	23. 98.3	98.6	98.9	50	54	58	14	16	15	79	82	79
	24. 98.1	98.8	98.8	58	54	56	15	16	15	79	85	82
	25. 98.1	99.1	.....	56	56	.....	15	16	.....	79	85	.....
	26. 98.3	98.5	98.8	54	54	54	15	16	16	79	84	81
	27. 98.2	98.9	98.8	54	56	52	14	16	14	79	86	78
	28. 98	98.7	98.5	52	52	52	14	15	15	79	85	81
	29. 98.1	99.2	98.7	52	54	62	14	16	15	79	83	80
	30. 97.9	99.1	.....	54	62	.....	14	15	.....	77	86	.....
	98.2	99	98.8	55.1	55.6	59.7	14.6	15.7	15.4	79	84.7	81
July 1846.	2. 98.3	99	99.3	62	56	62	15	16	16	79	84	81
	3. 98.3	98.9	.....	54	54	.....	15	15	.....	79	86	.....
	4. 98.1	98.9	98.5	54	52	75	14	16	16	79	86	82
	5. 98.3	98.6	.....	52	54	.....	15	16	.....	79	86	.....
	6. 98.5	99	98.8	60	56	56	16	16	16	79	86	82
	7. 98	98.6	98.4	52	56	80	15	17	16	79	85	80
	8. 98.3	98.8	98.6	60	50	52	15	15	15	78	83	81
	9. 98.2	98.9	99	54	56	60	14	16	15	79	86	81
	10. 98	98.6	98.8	54	54	54	14	17	16	79	86	81
	11. 98	.....	.....	56	.....	.....	14	.....	.....	80	.....	.....
	12. 98.4	99	99.3	54	54	60	16	15	15	78	85	82
	13. 98.2	99	99	52	56	60	15	15	16	79	86	81
	14. 97.7	98.7	98.9	54	54	56	15	16	15	79	86	80
	15. 98.4	99	98.9	56	56	80	14	17	15	80	86	82
	16. 98.4	98.9	98.9	56	56	58	15	16	16	79	82	82
	17. 98.1	98.8	99.1	50	56	56	14	15	16	76	84	81
	18. 98.1	98.6	99	52	56	58	15	16	16	79	86	82
	19. 98.1	.....	99	52	.....	58	14	.....	16	79	.....	82
	20. 98.3	99.1	99.3	52	58	56	15	17	15	78	86	82
	21. 98	98.8	.....	54	56	.....	14	17	.....	79	85	.....
	23. 98.3	98.8	99	56	56	58	15	15	17	79	84	81
	24. 98.3	98.8	99.1	54	50	64	15	16	15	78	83	82
	25. 98.2	98.6	99	54	52	56	15	17	16	79	83	81
	26. 98.2	98.8	98.8	50	50	58	15	15	15	79	85	81
	27. 98.1	99	98.9	54	54	56	15	17	15	79	84	82
	28. 98.2	99.2	98.7	52	58	68	14	16	15	78	84	81
	29. 98.4	98.9	.....	54	52	.....	14	16	.....	79	84	.....
	98.2	99	98.9	54.5	54.5	60.7	14.7	16	15.3	78.8	84.8	81.4

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
August 1846.	1. 98.2	98.8	98.5	56	54	70	15	16	17	78	86	82
	2. 98.1	98.7	99.2	54	54	62	15	15	16	79	87	81
	3. 98.2	99.1	99.2	52	58	60	14	17	16	79	86	82
	4. 98.1	98.9	98.9	54	56	64	15	16	16	79	86	82
	5. 98.2	99.2	98.9	52	54	60	15	16	15	79	83	79
	6. 98.2	99	99.1	54	56	70	15	16	16	75	84	81
	7. 97.9	99.1	99	52	60	60	15	16	15	77	86	82
	8. 98.3	98.7	98.7	58	56	60	15	16	16	79	83	80
	9. 98.1	98.6	98.8	54	54	56	15	15	16	79	85	81
	10. 98.2	98.9	98.9	54	54	60	15	16	15	79	87	83
	11. 98.2	98.4	99	54	54	62	14	14	16	78	83	81
	12. 98.3	99.2	98.9	56	60	64	15	16	16	80	86	82
	13. 98.5	99.1	98.8	56	54	60	15	15	16	79	84	81
	14. 98.1	98.9	99.2	54	58	64	15	17	16	79	86	82
	15. 98.4	99	98.7	54	58	54	15	16	15	80	87	82
	16. 98.3	.....	98.8	54	.....	56	15	.....	16	80	.....	83
	17. 98.3	98.9	98.9	54	56	54	14	16	16	79	85	79
	18. 98	98.8	98.9	54	52	64	15	16	16	77	86	83
	19. 98.4	99.2	99	56	56	60	14	16	16	80	86	82
	20. 98.3	98.9	.....	54	52	.....	15	16	.....	79	86	.....
	21. 98.4	99.3	99.1	62	60	62	16	17	16	80	88	83
	22. 98.2	99	99.3	54	54	60	14	16	16	79	86	81
	23. 98.2	98.8	98.8	54	54	60	14	17	16	79	87	78
	24. 98.2	99.1	99.2	54	54	54	14	16	16	79	87	82
	25. 98.2	99.4	98.8	52	54	60	14	16	16	78	82	80
	26. 98.3	98.9	99	54	54	62	14	15	15	78	84	83
	27. 98.2	98.7	98.8	54	58	60	14	16	16	78	82	78
	28. 98.3	99	98.5	54	54	54	15	15	16	78	86	82
	29. 98.3	98.9	98.9	54	56	60	14	15	15	79	84	81
	30. 98.2	.....	.....	56	.....	.....	15	.....	.....	79	.....	.....
	31. 98	99.1	99	58	58	64	15	16	16	79	86	82
	98.1	99	98.9	54.2	55.6	60.5	14.6	15.9	15.6	78.7	85.5	81.7
September 1846.	1. 98.2	99	98.8	56	58	56	14	17	16	79	86	79
	2. 98.2	98.8	99	54	56	56	14	16	16	79	85	83
	3. 98.2	99.1	.....	54	54	.....	15	16	.....	78	85	.....
	4. 98	99.2	99.2	52	56	62	15	16	16	78	85	84
	5. 98.2	98.9	98.9	54	54	78	15	17	17	80	87	83
	6. 98.1	98.9	98.8	56	56	60	15	15	15	80	87	79
	7. 98.1	98.9	98.4	54	52	54	15	15	16	80	84	79
	8. 97.7	98.8	99.2	52	54	60	15	15	16	78	86	83
	9. 98.4	98.9	98.7	56	56	62	15	15	15	79	86	82
	10. 98	99	98.9	54	56	54	14	15	15	80	87	83
	11. 98.3	99.1	98.8	54	60	62	15	16	16	81	83	81
	12. 98.2	98.6	99.1	56	52	58	14	14	14	80	82	81
	13. 98.2	98.7	98.5	54	50	56	15	15	16	78	86	82
	14. 98.3	99.1	98.1	56	54	64	15	16	16	78	86	81
	15. 98.5	98.8	98.9	52	56	56	15	16	16	79	85	82
	16. 97.9	.....	98.5	56	.....	60	15	.....	16	78	.....	80
	17. 98.2	99.3	98.6	58	60	60	15	16	16	79	85	80
	18. 98.2	99.1	98.9	54	56	60	15	16	16	78	84	81
	19. 98.2	99	99.2	54	52	58	14	15	15	79	86	82
	20. 98.3	99.2	98.7	52	58	56	14	15	15	77	86	80
	21. 98.3	99.2	99	58	60	60	15	16	15	79	86	78
	22. 98.2	98.9	98.8	56	56	56	15	16	16	79	85	79
	23. 98.6	99	99	54	52	80	14	15	17	79	85	81
	24. 98.5	99.4	99.2	62	58	60	15	15	16	78	86	82
	25. 98.3	99.1	98.7	60	62	60	15	16	15	80	82	79
	26. 98.1	99.2	98.5	56	56	80	14	16	16	77	84	79
	27. 98.5	99.1	99	62	54	62	15	16	16	78	85	82
	28. 98.2	99	99.1	54	56	62	14	15	15	79	85	81
	29. 98	99.1	98.7	52	56	56	15	15	16	77	85	80
	30. 98.2	98.7	98.7	54	58	56	15	16	16	77	85	81
	98	99	98.8	55	54	60.8	14.3	15.9	16	78.7	85.1	81.3

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
October 1846.	1. 98.1	.....	.....	52	.....	.....	15	.....	.....	79	°	°
	2. 98.4	98.8	98.7	54	54	54	15	16	15	78	82	80
	4. 97.9	98.5	58	52	54	15	15	15	15	77	83	79
	5. 98.3	99.1	99	56	56	64	15	15	16	77	85	80
	6. 98.1	98.7	.....	52	54	.....	14	15	.....	78	86	.....
	7. 98.5	99.1	98.9	62	58	60	15	16	16	79	84	80
	8. 98.4	99.3	99	52	56	74	15	16	16	78	85	81
	9. 98.3	99.2	99.3	52	56	62	15	16	15	78	86	82
	10. 97.9	98.9	98.8	54	56	72	15	15	16	78	86	79
	11. 98.2	.....	.....	56	.....	.....	15	.....	.....	78	.....	.....
	13. 98.2	99	99.4	50	56	64	14	16	15	79	86	82
	14. 98.3	98.7	.....	50	56	.....	14	15	.....	78	87	.....
	15. 98.4	98.9	98.9	60	54	62	14	16	16	80	86	81
	16. 98.5	98.7	99	52	56	62	14	15	16	80	85	81
	17. 98.1	99	98.7	50	52	56	14	16	15	78	86	81
	18. 98.2	98.9	99	50	56	56	14	14	15	77	86	80
	19. 98	98.9	99.1	52	54	60	14	15	15	76	86	80
	20. 98.3	99.1	.....	52	56	.....	14	16	.....	78	86	.....
	21. 98.2	98.9	99.2	60	52	60	16	15	16	79	88	83
	22. 98	98.8	98.8	52	50	60	14	16	15	80	87	82
	23. 98.1	99	98.8	50	56	56	14	16	16	78	87	81
	24. 98.3	99	98.4	54	60	64	15	15	17	79	83	80
	25. 98.2	98.8	99	52	54	60	14	16	15	80	83	82
	26. 98.2	98.9	.....	54	52	.....	14	15	.....	78	84	.....
	27. 98.2	98.7	99.2	54	54	62	14	15	17	78	85	81
	28. 97.8	98.8	98.9	52	54	56	14	15	16	77	85	82
	29. 98.2	.....	98.6	54	.....	70	14	.....	15	79	.....	81
	30. 98.3	98.6	.....	60	58	.....	14	16	.....	79	85	.....
	31. 98.1	99.4	98.7	60	62	56	15	16	16	76	82	78
	98.2	99	99	52	55	61	14.4	15.4	15.3	78.2	85.1	81.2
November 1846.	1. 98.2	99.2	98.6	56	58	58	15	16	16	75	84	79
	2. 98.1	99.2	98.7	54	58	56	14	16	15	77	85	81
	3. 98	98.7	98.8	54	52	58	14	14	16	77	85	81
	4. 98.3	99.1	.....	54	54	.....	15	16	.....	78	85	.....
	5. 98	99.3	99.1	54	56	60	15	16	15	79	85	80
	6. 98	98.7	.....	54	52	.....	14	15	.....	78	86	.....
	7. 97.9	99.1	98.8	56	50	52	14	16	15	75	82	78
	8. 98	98.5	98.9	52	52	54	14	15	15	77	83	80
	9. 98.2	98.8	99.1	56	56	60	15	16	15	78	86	81
	10. 98	99.2	99.2	56	60	62	15	16	16	78	87	82
	11. 98.1	99.2	99	56	60	60	15	16	16	79	87	82
	12. 98	.....	.....	52	.....	.....	14	.....	.....	78	.....	.....
	13. 98.3	99.1	99.4	52	54	64	15	16	16	79	87	82
	14. 98.3	98.9	.....	56	56	.....	15	17	.....	78	87	.....
	15. 98.5	99.1	98.9	66	58	60	15	15	16	78	86	82
	16. 98.3	99	98.8	56	56	60	14	16	16	79	87	80
	17. 98.2	98.2	98.6	56	52	56	15	15	15	79	78	79
	18. 98.4	.....	.....	56	.....	.....	.....	14	.....	.....	.....	.....
	19. 98.1	99	99	58	60	66	15	16	16	79	79	80
	20. 97.9	.....	98.8	66	.....	62	16	.....	16	79	.....	81
	21. 98	98.7	.....	56	54	.....	14	16	.....	78	85	.....
	22. 98.4	98.7	99.1	58	58	58	14	16	15	78	85	81
	23. 98.2	98.7	98.9	56	56	62	15	16	16	77	84	81
	24. 98.2	98.9	98.8	56	56	58	15	16	16	78	85	80
	25. 98	98.8	99	56	54	60	15	15	15	76	83	78
	26. 97.9	99.1	98.4	56	60	70	15	17	16	76	83	79
	27. 98.3	98.8	98.7	56	56	58	15	17	16	78	84	81
	28. 98.1	98.6	99.2	54	54	62	14	15	16	75	84	80
	29. 98.1	98.9	98.8	54	54	64	15	16	16	77	83	80
	30. 98.3	.....	98.8	54	.....	62	15	.....	16	76	.....	80
	98.1	98.9	98.8	56.2	55.4	60.1	14.6	15.8	15.6	77.4	84.4	80

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
December 1846.	1. 98.3	98.9	98.6	54	54	62	15	16	16	78	79	78
	2. 98.3	99.2	.....	56	64	.....	15	16	.....	78	77	.....
	3. 98	98.8	98.9	54	54	68	15	15	16	75	79	79
	4. 97.9	98.5	.....	54	52	.....	15	15	.....	77	77	.....
	5. 98.3	98.7	98.8	64	56	74	16	16	17	77	81	78
	6. 98.2	98.4	99	60	54	64	15	16	15	78	80	78
	7. 98.1	98.8	98.8	54	50	76	15	15	16	76	79	78
	8. 97.9	98.8	98.9	50	50	60	15	15	16	76	80	75
	9. 97.9	99.3	98.7	52	56	60	14	16	16	75	82	78
	10. 98	99	98.9	50	56	56	15	15	15	75	82	78
	11. 97.9	98.7	98.5	56	52	60	15	15	16	75	82	77
	12. 97.9	98.7	98.8	54	56	60	15	16	15	75	82	78
	13. 98.1	98.7	99.2	56	56	64	15	16	16	75	82	77
	14. 97.9	98.8	99.1	54	56	58	15	16	16	75	82	79
	15. 98.1	98.5	98.5	56	54	60	15	16	15	75	77	76
	16. 98.1	99.2	99	54	60	64	15	16	16	76	82	78
	17. 98.3	.....	98.7	56	.....	56	15	.....	16	77	.....	78
	18. 98.1	.....	.....	56	.....	.....	15	.....	.....	76	.....	.....
	19. 98.2	98.8	99.2	54	56	62	14	17	16	76	84	79
	20. 98.3	98.7	.....	56	62	.....	15	16	.....	78	83	.....
	21. 98.3	98.7	.....	56	62	.....	15	16	.....	78	83	.....
	22. 98.7	.....	.....	68	.....	.....	16	.....	.....	77	.....	.....
	23. 97.9	98.9	98.9	62	54	62	15	17	16	76	82	78
	24. 97.9	98.8	99.1	52	54	62	14	15	16	76	82	78
	25. 98.3	98.7	.....	52	54	.....	14	15	.....	76	81	.....
	28. 98	99	99	52	56	70	15	17	16	75	75	77
	29. 98.1	.....	.....	52	.....	.....	14	.....	.....	77	.....	.....
	30. 97.9	98.9	98.6	60	56	58	14	15	16	73	81	71
	31. 98.1	98.8	98.9	52	56	56	15	16	14	73	80	78
	98.1	98.9	98.9	55.3	55.3	63.5	14.5	15.8	15.8	76	80.5	77.4
January 1847.	1. 98.4	98.8	98.7	56	54	66	14	16	16	73	82	78
	2. 98.3	98.8	.....	64	56	.....	14	16	.....	76	82	.....
	3. 98.5	.....	99	60	.....	60	15	.....	15	76	.....	78
	4. 98.1	98.9	98.9	56	56	60	15	16	16	77	82	79
	5. 98.1	99.3	98.7	54	54	56	14	16	14	76	82	78
	6. 98.3	99.2	99.1	54	54	60	14	15	16	76	82	78
	7. 98	99.1	98.9	50	60	60	14	16	15	76	82	77
	8. 98.3	98.9	98.9	52	58	62	14	16	16	76	83	78
	9. 98.5	99.5	98.9	58	62	62	15	16	16	75	83	77
	10. 97.9	98.4	98.5	56	52	56	14	15	14	75	79	76
	11. 98.4	98.8	98.5	60	54	54	15	16	15	75	79	77
	12. 97.9	98.9	98.9	54	56	60	15	16	16	74	81	77
	13. 98	99	98.9	54	56	62	15	16	15	74	81	78
	14. 97.9	98.9	99.1	50	56	64	14	16	15	74	82	77
	15. 98	98.8	98.9	52	52	58	14	15	15	74	81	77
	16. 98.3	98.8	99	52	52	58	14	14	14	74	82	77
	17. 98.5	99	98.8	60	54	66	15	15	14	74	81	77
	18. 98	99	98.9	54	54	62	14	14	14	74	81	77
	19. 98.3	.....	.....	56	.....	.....	15	.....	.....	75	.....	.....
	21. 98.3	99	98.7	56	54	62	15	16	15	73	79	77
	22. 98.2	.....	.....	56	.....	.....	15	.....	.....	74	.....	.....
	23. 98	98.6	99	54	48	64	14	14	16	74	81	78
	24. 98	98.4	98.6	52	54	60	14	15	15	74	81	77
	25. 98.5	99.2	99.1	54	56	68	14	15	15	75	82	77
	26. 97.9	98.9	98.7	54	56	56	14	16	15	74	82	77
	28. 98.1	.....	.....	56	.....	.....	14	.....	.....	74	.....	.....
	29. 97.9	99.1	.....	52	64	.....	14	16	.....	73	80	.....
	30. 98.5	98.9	99.3	58	58	66	14	15	15	73	82	76
	31. 97.9	98.4	98.5	54	52	58	15	15	15	74	81	77
	98.1	98.9	98.8	54.8	55.3	60.8	14.4	15.4	15	74.6	81.3	77.3

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
February 1847.	1. 97.9	99.2	98.7	52	60	60	14	16	15	73	82	75
	2. 97.9	99.2	98.3	56	60	60	14	16	15	72	82	74
	3. 98.1	.....	.....	56	.....	.....	14	.....	.....	71		
	4. 97.9	98.9	.....	56	62	.....	14	15	.....	71	81	
	5. 97.9	99	99.1	56	56	64	14	16	16	71	81	74
	6. 97.7	99	.....	58	56	.....	14	15	.....	70	79	
	7. 98.1	98.5	99.1	58	60	60	15	15	15	71	81	75
	8. 97.8	98.7	99	54	56	64	14	16	16	73	82	75
	9. 97.8	99.2	98.9	54	60	64	14	16	15	72	81	78
	10. 98.2	98.8	98.9	56	54	64	14	15	15	74	82	78
	11. 98.2	98.9	99.1	56	54	62	14	16	16	73	83	77
	12. 98.2	98.7	98.6	58	56	58	15	16	15	74	80	76
	13. 98.3	98.5	.....	56	50	.....	14	14	.....	72	80	
	14. 98.2	98.7	98.8	58	56	56	16	14	15	74	79	75
	15. 98.1	98.8	98.7	54	60	58	14	16	15	71	82	76
	16. 97.7	98.5	98.8	58	54	60	15	16	15	74	82	78
	17. 98	98.8	99.1	58	58	58	15	16	15	75	82	77
	18. 97.8	98.9	98.6	54	58	76	14	16	16	74	82	78
	19. 97.8	98.8	98.8	58	58	60	16	16	15	74	81	77
	20. 98.2	.....	.....	58	.....	.....	14	.....	.....	74		
	21. 98.2	.....	.....	54	.....	.....	15	.....	.....	75		
	23. 98	99	98.9	56	54	64	14	16	16	76	83	79
	24. 97.9	98.9	98.9	52	60	62	14	15	15	75	83	77
	25. 98.2	99.3	.....	54	64	.....	14	16	.....	74	82	
	26. 98.1	98.9	99.2	56	56	62	14	14	15	74	81	76
	27. 97.9	98.8	98.1	56	56	60	14	15	16	72	82	76
	28. 98	98.4	.....	54	54	.....	14	16	.....	74	83	
	98	98.8	98.8	55.5	57.6	61.7	14.2	15.5	15.3	73	81.5	76.3
March 1847.	1. 98	98.9	99.3	52	54	64	15	16	15	74	83	76
	2. 98.1	98.6	98.7	54	56	56	14	16	15	75	84	78
	3. 98.2	99	98.6	54	60	80	14	15	16	75	83	78
	4. 98.4	98.7	99	62	60	66	15	16	16	76	83	78
	5. 98.1	98.8	99.2	52	54	68	14	16	16	75	84	77
	6. 97.9	98.8	98.5	54	56	62	14	15	15	75	84	77
	7. 98.2	98.5	98.9	54	54	64	14	15	15	74	84	77
	8. 98.1	98.8	98.9	54	54	62	14	15	16	74	84	76
	9. 97.9	98.7	98.9	54	52	56	14	16	15	74	83	78
	10. 98.4	98.8	98.9	56	56	66	15	16	16	75	84	78
	11. 98.1	98.8	98.9	56	50	64	15	16	16	74	83	76
	12. 98.1	.....	.....	54	.....	.....	15	.....	.....	74		
	13. 98.2	99.2	99.3	56	58	60	15	15	15	74	83	78
	14. 98.2	98.9	98.5	56	60	60	15	15	15	75	84	79
	15. 98	99.1	99.2	56	62	60	15	16	16	76	85	78
	16. 98.3	98.8	98.4	54	54	60	15	16	15	75	83	76
	17. 98.4	99.2	98.8	56	54	62	15	15	16	73	75	76
	18. 98	98.8	99.1	52	56	70	14	16	16	75	84	78
	19. 98.2	98.7	98.8	52	54	60	15	16	16	75	83	78
	20. 98.2	98.8	98.9	56	52	62	15	15	16	76	83	77
	21. 98.2	98.7	98.9	52	52	60	14	15	15	74	83	77
	23. 98.1	99.1	98.7	58	60	60	14	16	15	75	83	76
	24. 98.1	99.2	.....	60	64	.....	14	16	.....	75	82	
	98.1	98.8	98.9	54.8	59.2	62.7	14.5	15.6	15	74.6	83.5	77.1

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
April 1847.	1. 98.3	99	99.1	52	70	66	14	17	15	72	78	75
	2. 98.2	98.7	98.1	54	56	66	14	16	16	76	81	74
	3. 98.2	98.7	99.2	54	68	70	14	16	16	73	79	75
	4. 98.2	98.6	98.3	54	52	66	15	14	16	72	86	72
	5. 98	.....	.....	54	.....	.....	14	.....	.....	70		
	8. 98.1	98.3	98.6	54	54	60	14	15	15	74	83	77
	9. 97.9	98.7	98.8	54	54	60	14	15	15	75	83	78
	10. 98.2	98.2	99	52	52	66	14	15	16	74	78	76
	11. 98.3	98.6	98.8	50	54	56	14	15	16	74	81	78
	12. 98	98.7	98.4	56	54	56	15	16	15	75	83	77
	13. 97.8	98.7	98.7	54	54	64	14	15	16	73	77	78
	14. 97.9	98.7	98.7	56	56	64	14	15	15	76	82	77
	15. 97.9	99.2	99	54	64	70	15	15	15	75	82	78
	16. 98.3	98.5	98.8	54	54	60	15	15	16	75	82	78
	17. 97.7	99	.....	58	56	.....	14	15	.....	75	83	
	18. 98.2	98.4	99.1	60	56	60	15	15	15	75	83	79
	19. 98.3	98.7	99	56	56	62	15	16	16	75	84	78
	20. 98.2	98.9	99.1	56	58	54	13	16	15	75	81	77
	21. 97.5	99	98.8	54	60	58	14	17	16	76	83	78
	22. 98.2	98.7	98.5	56	54	62	14	16	16	75	83	78
	23. 98.1	98.7	99.1	58	54	70	14	16	16	76	84	79
	24. 98.3	99	98.8	54	56	70	14	15	15	76	84	78
	25. 98.2	.....	.....	56	.....	.....	14	.....	.....	75		
	26. 98.6	98.7	99	56	56	62	14	16	16	76	83	79
	27. 98	99	98.9	54	54	60	14	16	15	76	84	78
	28. 97.9	99	.....	56	56	.....	14	15	.....	75	84	
	29. 98.4	98.9	98.9	58	54	56	15	16	15	76	85	78
	30. 98.2	98.8	99.2	58	54	58	14	16	15	76	83	78
	98.1	98.7	98.8	55	56.4	62.3	14.2	15.5	15.6	74.7	82.2	77.1
May 1847.	1. 97.8	99.2	98.5	56	58	58	14	16	16	76	84	79
	2. 98.3	98.7	98.7	56	52	62	14	15	15	77	84	79
	3. 98.4	98.8	99.2	54	58	60	14	16	16	76	85	79
	4. 98.1	98.7	98.3	56	60	52	14	16	15	75	83	77
	5. 98.4	98.9	98.9	58	56	60	14	16	16	75	84	79
	6. 98.4	98.7	.....	56	58	.....	15	17	.....	76	84	
	7. 98.4	98.9	99.2	56	58	58	15	17	15	77	85	79
	8. 98.2	99.2	99.2	54	60	72	15	16	16	77	85	79
	9. 98	99.2	99	54	60	66	15	16	16	77	84	78
	10. 98.1	98.9	98.7	60	58	58	15	15	16	75	83	78
	11. 98	98.7	.....	56	58	.....	15	16	.....	75	84	
	12. 98.2	98.8	98.9	58	56	66	14	16	15	76	84	79
	13. 97.9	99.1	98.9	56	56	64	15	15	16	77	84	79
	14. 98.1	98.9	98.6	54	64	58	15	16	15	78	87	80
	15. 98.1	99.1	98.7	56	62	58	15	16	15	78	86	79
	16. 98.2	98.8	99.2	54	58	62	15	15	16	78	86	80
	17. 98.1	99.1	99.2	56	58	64	15	16	16	77	87	80
	18. 98.3	98.6	98.7	56	54	58	14	16	15	77	84	79
	19. 98.4	99	.....	56	62	.....	14	16	.....	77	87	
	20. 98.1	98.7	99.2	60	56	64	15	16	16	78	86	81
	21. 98.1	98.9	.....	58	60	.....	14	15	.....	78	86	
	22. 98.3	98.8	98.6	62	56	66	14	16	16	78	87	82
	23. 98.2	98.8	99.1	60	54	60	15	15	15	79	85	80
	24. 98.4	.....	.....	58	.....	.....	14	.....	.....	77	.....	
	98.1	98.9	98.8	56.6	57.8	61.3	14.5	15.8	15.6	76.7	85	79.2

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
October 1847.	1. 98.2	99	99.2	56	56	60	15	16	17	77	85	81
	2. 98.2	99	99.1	56	58	60	15	15	17	78	86	83
	3. 98	98.9	98.6	56	56	56	14	15	16	78	85	81
	4. 98.3	98.9	99.2	58	58	60	15	15	16	78	87	81
	5. 98.5	98.8	98.8	56	56	56	15	15	16	78	83	78
	6. 98	98.7	99	56	52	64	14	16	17	77	85	79
	7. 98	99	98.5	54	56	54	15	15	16	78	86	78
	8. 98.2	99.6	98.9	56	62	58	15	16	16	77	85	81
	9. 98	99.1	98.8	56	54	54	15	16	15	78	86	82
	10. 98.3	99	98.7	54	56	58	15	15	16	79	87	81
	11. 98.5	98.8	99.1	56	58	56	15	16	16	80	83	81
	12. 98.4	98.8	98.7	56	58	54	15	14	16	78	86	79
	13. 98	99.2	98.8	52	60	60	14	15	16	78	85	80
	14. 98.2	99	98.8	58	58	15	16	16	16	77	85	80
	15. 98	98.8	98	54	56	58	15	15	16	77	84	80
	16. 98.1	99.1	98.6	56	54	56	15	17	16	78	86	80
	17. 98	98.9	99.1	54	56	60	15	15	16	78	86	80
	18. 97.9	98.7	98.6	54	52	56	15	15	16	78	86	80
	19. 98.1	99	98.7	54	52	54	14	15	16	78	87	81
	20. 98	99.2	98.6	52	58	54	14	15	15	78	86	82
	21. 98	99	99.1	52	56	60	14	15	16	78	85	80
	22. 98.1	99	98.4	58	54	56	14	15	15	78	84	79
	23. 97.9	99.6	98.9	52	58	60	14	15	15	77	86	80
	24. 98.1	98.9	98.5	56	56	54	15	15	15	77	85	80
	25. 97.7	98.5	98.3	54	50	54	15	15	15	79	79	78
	26. 97.9	98.2	98.6	52	54	54	14	15	15	77	80	79
	27. 97.9	99.2	98.4	56	56	54	15	14	15	77	85	77
	28. 98.1	98.7	98.7	54	52	56	14	15	15	77	83	79
	29. 98	98.8	98.8	54	58	58	14	14	15	77	82	80
	30. 98.1	98.8	99	56	58	60	14	15	16	76	85	80
	31. 98	98.9	98.8	52	60	58	14	14	15	77	85	81
	98	99	99	54.7	56	55.7	14.5	15.1	15.7	77.7	84.8	80
November 1847.	1. 98.2	99.7	99.1	56	66	60	15	15	16	77	84	79
	2. 98.3	99	98.9	54	62	58	14	15	15	77	83	82
	3. 98.1	98.7	98.9	56	50	58	15	15	16	78	86	82
	4. 98	98.9	99.1	54	52	58	14	14	15	78	86	82
	5. 98	98.8	98.9	50	56	56	15	15	15	78	86	80
	6. 98.2	99.4	98.8	56	54	62	14	15	16	78	86	82
	7. 98.3	99.3	.....	56	62	.....	14	16	.....	79	87	
	8. 98	98.8	98.9	56	56	60	14	14	15	78	84	79
	9. 98	98.5	98.9	56	52	54	14	16	16	78	86	81
	10. 98.2	99	98.9	56	56	56	14	15	16	79	86	81
	11. 98.4	98.8	98.8	58	58	56	14	15	16	79	85	81
	12. 98.2	99.3	99	56	56	62	14	15	15	79	84	81
	13. 98.4	99.5	99	58	60	58	15	16	16	79	86	81
	14. 98.6	99.1	98.6	60	58	56	15	16	15	78	83	78
	15. 98	98.7	97.7	56	50	58	15	15	16	75	76	76
	16. 98.4	98.5	97.8	54	50	58	15	16	16	76	78	76
	17. 98.3	98.5	98.8	54	52	54	14	15	16	75	79	77
	18. 98.2	99.4	.....	54	62	.....	15	16	.....	77	83	
	19. 98.2	98.5	98.6	58	52	58	15	15	15	75	82	76
	20. 98.1	98.9	99	52	56	58	15	15	15	74	83	78
	21. 98	98.2	98.5	56	54	64	14	15	16	74	77	77
	22. 98.2	99.2	98.6	56	62	60	14	16	16	75	78	77
	23. 98.2	99.2	98.7	60	70	60	15	15	16	75	83	78
	24. 98.2	98.8	99.3	54	54	64	14	15	16	75	75	79
	25. 98.2	99.2	99	54	56	66	15	15	17	77	83	79
	26. 98.2	98.9	98.5	54	56	56	14	15	15	77	82	78
	27. 98	98.6	98.7	54	56	62	15	15	16	74	81	78
	28. 98	98.6	98.3	54	54	56	14	15	15	75	82	76
	29. 98.1	98.9	99	52	54	68	15	15	15	77	77	78
	30. 98.4	99.3	98.6	58	58	54	15	14	15	76	81	78
	98.1	98.8	98.8	53.3	54.8	59.2	14.5	15.1	15.2	76.7	82.3	79

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
December 1847.	1. 98.1	98.7	98.9	52	56	62	14	15	15	77	83	77
	2. 97.9	98.6	98.6	52	52	58	14	15	16	74	81	68
	3. 97.9	99.2	99.2	52	58	68	14	14	16	75	73	77
	4. 97.9	98.7	98.7	52	54	60	15	15	16	74	82	73
	5. 97.7	99.1	97.8	54	60	56	14	15	14	68	82	73
	6. 98.2	98.4	98.5	56	58	56	14	15	16	72	83	78
	7. 97.9	98.6	98.2	56	54	56	14	15	16	77	83	78
	8. 98.1	99.1	98.8	54	58	58	14	15	15	77	84	78
	9. 98	99.2	98.5	54	62	58	15	16	15	76	83	77
	10. 98.2	98.7	98.5	54	54	60	15	15	16	76	83	78
	11. 98.3	98.8	98.6	54	54	60	15	15	16	77	81	78
	12. 98.3	98.9	98.7	54	50	58	14	14	16	77	81	77
	13. 98.2	99.1	98.8	56	56	60	14	15	15	79	80	78
	14. 98	98.9	98.4	52	52	64	14	14	16	73	77	77
	15. 97.9	99.2	98	52	58	64	14	15	16	76	80	77
	16. 97.9	98.8	98.6	52	56	60	14	15	16	75	80	76
	17. 98.1	98.7	98.7	52	54	60	15	15	15	76	81	77
	18. 97.9	98.2	98.5	54	50	56	14	15	15	76	81	77
	19. 98.1	98.9	98.5	52	60	58	14	15	15	75	82	77
	20. 98.2	98.7	98.6	56	56	60	14	14	16	76	82	78
	21. 98	98.8	98.7	52	56	58	14	15	15	75	82	78
	22. 98.1	.....	98.9	52	.....	66	13	.....	15	75	.....	77
	23. 97.9	98.8	98.1	54	56	62	14	14	15	75	82	76
	24. 98.1	99.1	.....	52	58	.....	14	16	.....	74	80	.....
	27. 98.1	98.5	98.7	54	52	56	14	14	15	73	81	76
	28. 97.9	98.4	98.3	52	56	58	14	15	15	74	82	76
	29. 98	98.4	98.9	50	52	62	14	14	15	73	81	75
	30. 97.7	99.2	99.4	50	60	58	14	15	15	73	81	78
	31. 98.1	98.5	98.4	52	50	58	14	15	15	75	79	78
	98	98.8	98.3	52.9	53.5	58	14.1	14.6	15.3	74.5	81.1	76.9
January 1848.	1. 98	99	98.8	56	60	66	14	15	14	76	80	77
	2. 98.1	99.2	98.9	54	56	60	15	15	15	75	81	78
	3. 98	99.1	99	54	60	66	14	15	15	76	82	78
	4. 98.2	99	98.8	52	56	58	14	15	15	75	80	76
	5. 98.1	99.1	99	52	58	58	14	14	16	75	80	76
	6. 97.9	99.1	98.5	54	58	58	14	15	15	75	80	78
	7. 98.2	98.7	98.8	56	54	58	14	15	15	74	81	78
	8. 98.3	99.1	98.8	56	62	64	14	16	16	75	83	78
	9. 98.3	98.8	99.1	52	56	60	15	15	16	74	82	78
	10. 98.4	98.3	98.8	54	58	60	14	15	16	73	81	71
	11. 97.9	98.4	98.5	52	54	60	14	16	15	73	81	75
	12. 98.1	98.3	98.7	58	54	66	14	15	16	73	82	77
	13. 97.9	98.6	98.5	54	58	64	14	16	15	74	80	77
	14. 98	99.1	98.9	56	60	56	14	16	14	73	81	77
	15. 98	98.9	99	56	62	60	14	16	15	73	81	78
	16. 98.3	99	98.7	56	52	58	14	15	16	75	80	78
	17. 98.1	98.8	98.8	54	56	60	15	15	15	75	75	75
	18. 97.9	98.6	98.9	56	56	56	14	15	16	73	77	77
	19. 98.3	98.8	98.8	54	54	58	14	15	15	74	80	77
	20. 98.3	99	98.5	56	58	56	14	15	16	74	81	77
	21. 97.9	98.6	98.8	54	58	58	14	16	16	74	80	78
	22. 98.1	98.7	98.7	56	56	58	14	15	15	74	82	78
	23. 98.1	99.1	98.7	56	58	54	14	14	14	73	81	76
	24. 98.3	99	98.8	52	54	60	14	14	15	73	79	76
	25. 97.8	98.9	98.4	52	54	60	14	15	15	73	80	76
	26. 98.2	98.9	99	53	56	56	14	15	16	73	81	77
	27. 97.9	98.8	98.8	56	54	56	14	15	15	69	80	74
	28. 98	98.8	98.9	54	56	62	14	15	15	68	80	76
	29. 98	99.3	99.1	54	60	62	14	16	15	72	80	74
	30. 98.3	99.3	98.8	56	56	56	14	14	15	71	82	77
	31. 98.1	98.9	99	54	56	54	15	15	15	74	82	78
	98.1	98.9	98.8	54.5	56.8	59.3	14.1	14.9	15.2	74.1	80.5	76.6

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
February 1848.	1. 98.4	99	98.8	56	56	56	14	15	15	73	81	78
	2. 98.2	99	98.8	54	58	56	15	15	15	73	83	75
	3. 97.9	99.2	98.9	56	60	58	15	15	15	75	82	78
	4. 98	98.8	98.6	54	62	56	14	16	15	74	81	78
	5. 98.1	98.8	98.9	56	60	62	14	16	15	73	83	77
	6. 98	98.8	98.8	56	56	60	14	15	16	72	82	77
	7. 98	98.9	99.3	56	54	62	14	14	16	73	81	78
	8. 98	99.2	98.8	57	58	56	14	16	15	73	83	77
	9. 98.1	98.7	99.2	56	58	64	15	15	16	74	83	78
	10. 97.9	99.6	99	54	54	56	14	15	16	74	81	77
	11. 98	98.5	98.9	55	56	62	15	15	16	74	80	78
	12. 98.1	98.5	99	56	54	64	15	16	17	73	81	77
	13. 98	98.4	98.5	52	56	56	14	15	16	73	81	77
	14. 98	99.4	98.9	56	58	60	14	15	16	74	83	78
	15. 98	98.6	99.3	52	56	64	15	15	15	74	83	77
	16. 98	98.7	98.9	57	56	62	15	15	16	73	82	78
	17. 98.3	99	99.2	58	58	58	16	16	16	75	81	78
	18. 98.1	98.3	98.8	54	52	58	15	15	15	73	77	77
	19. 97.9	99.2	98.7	52	56	56	14	15	16	73	81	77
	20. 98	99	98.7	56	54	56	14	15	15	74	81	78
	21. 97.7	98.9	98.9	52	56	58	15	16	16	73	81	77
	22. 97.8	99.2	99.1	52	58	62	15	14	15	73	83	78
	23. 98.2	99	98.9	56	56	64	15	15	16	75	82	79
	24. 97.9	99.1	99	54	64	64	14	16	16	74	83	79
	25. 97.9	98.7	99	58	56	58	15	15	15	74	82	78
	26. 97.9	98.7	.....	54	56	.....	15	16	.....	74	81	.....
	27. 97.8	99.2	99	56	56	60	14	15	15	74	82	78
	28. 98.1	98.8	98.8	54	54	62	14	15	15	75	77	77
	29. 97.8	98.6	98.9	52	56	62	15	15	15	74	81	78
	98	98.8	98.8	54.9	57	59.7	14.5	15.1	15.5	73.6	82.1	77.5
March 1848.	1. 98	98.8	99.3	54	56	62	15	16	16	75	83	79
	2. 98.1	99.6	99.2	56	58	66	15	16	16	76	84	80
	3. 98.2	98.8	99	56	56	64	15	15	17	76	83	80
	4. 97.8	98.9	.....	52	56	.....	14	15	.....	73	81	.....
	5. 98.1	99.5	99	60	56	60	14	15	16	74	82	78
	6. 97.9	98.7	98.6	56	56	56	14	15	15	74	82	79
	7. 97.8	98.3	98.9	52	56	56	14	15	15	74	82	77
	8. 97.9	99.5	99	52	74	58	14	16	15	74	83	79
	9. 98.1	99.4	.....	54	60	.....	14	14	.....	76	82	.....
	10. 98.4	99.1	99	58	56	62	15	14	15	75	83	78
	11. 98.1	99	98.7	54	60	62	14	16	16	74	81	78
	12. 98.1	98.9	98.9	54	62	60	15	15	16	74	83	78
	13. 98	98.9	99.1	56	56	60	14	15	16	73	82	78
	14. 98.1	98.9	99	58	60	62	15	16	15	75	82	79
	15. 98	98.8	98.7	56	56	56	14	15	15	76	83	78
	16. 98.3	98.7	99.2	56	58	62	15	16	16	76	80	77
	17. 98.1	98.7	98.9	54	54	62	14	14	15	75	83	79
	18. 98.1	.....	.....	56	.....	.....	14	.....	.....	76	.....	.....
	19. 98.2	99.2	99	56	60	54	15	15	15	75	83	82
	20. 98.2	98.7	98.6	54	54	54	14	16	15	75	76	77
	21. 98	98.7	99.1	52	56	56	15	16	15	73	82	78
	22. 98	99	99	56	56	58	15	15	16	75	82	79
	23. 98.1	98.8	98.9	54	58	60	14	15	15	77	83	79
	24. 98.3	98.9	99	54	56	62	14	15	16	75	82	78
	25. 98	98.6	98.9	56	56	56	14	15	15	76	79	78
	26. 98.2	98.9	98.5	54	58	60	14	15	14	75	81	79
	27. 97.9	98.7	99.1	52	52	56	14	15	15	75	83	78
	28. 97.9	99.1	98.8	52	54	60	14	15	15	76	84	80
	29. 98	99.2	99.2	54	64	66	14	16	16	77	85	77
	30. 98.2	99.1	99.1	54	56	60	14	15	14	77	83	78
	31. 98	99.4	99	58	58	62	14	15	15	78	79	75
	98	98.9	98.9	54.9	57.6	59.7	14.3	15.5	15.4	75.1	81.9	78.2

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
April 1848.	1. 98.2	99	98.6	56	58	58	15	15	14	75	79	78
	2. 98.1	99.2	99	60	56	58	14	16	15	73	81	77
	3. 97.9	98.8	98.9	54	56	60	15	15	16	71	81	77
	4. 98	98.7	.....	54	58	.....	14	15	.....	71	81	
	5. 98.2	98.8	98.9	60	60	64	15	16	15	72	83	78
	6. 98.1	99.3	98.7	56	58	64	14	15	16	73	85	79
	7. 98.2	99.2	99.2	56	58	64	15	15	16	76	85	79
	8. 97.8	99.3	99.3	54	58	58	15	15	15	77	83	81
	9. 98.4	.....	.....	58	.....	.....	15	.....	.....	75		
	25. 98.1	98.9	98.9	54	54	62	14	15	15	75	80	77
	26. 98	98.7	98.9	52	56	60	15	16	16	77	85	81
	27. 98	98	99	54	58	60	15	15	15	78	84	79
	28. 97.9	99	98.9	52	58	60	14	15	15	77	85	79
	29. 97.7	98.5	98.8	52	56	62	14	16	15	76	84	79
	30. 97.9	99	99.1	52	64	62	15	16	16	77	85	82
	98	98.9	98.9	54.9	57.7	60.9	14.7	15.2	15.3	74.8	82.9	78.1
May 1848.	1. 98.3	99.1	98.7	52	58	60	14	15	15	78	86	81
	2. 97.9	98.7	98.6	52	56	58	15	15	16	79	85	79
	3. 98.1	98.7	99	56	54	60	14	15	16	77	85	80
	4. 97.9	98.8	99	52	56	54	14	16	16	78	87	82
	5. 98	99.2	99	56	54	60	15	16	15	79	85	81
	6. 98.2	99	99.1	54	56	70	15	14	16	79	86	81
	7. 98	99.1	99	58	56	60	14	15	16	78	86	82
	8. 98.1	98.8	99.1	54	56	60	14	15	15	78	86	82
	9. 98.3	99.3	98.4	56	58	58	15	15	15	79	85	78
	10. 98.4	99.2	99	58	58	66	15	14	16	78	84	80
	11. 98.2	.....	.....	58	.....	.....	14	.....	.....	78		
	98.1	99	98.9	55.1	56.2	60.6	14.3	15	15.6	78.2	85.6	80.6
June 1848.	7. 98	98.6	.....	56	60	.....	15	16	.....	78	81	
	8. 98	98.9	98.6	52	58	62	14	15	15	78	84	81
	9. 97.9	98.6	98.8	54	58	64	14	16	14	77	85	82
	10. 98.8	98.9	99	54	58	60	15	15	16	78	85	80
	11. 97.8	99	98.9	52	56	56	14	14	14	77	86	81
	12. 97.9	98.9	98.9	52	54	58	14	15	14	78	83	80
	13. 98.1	99	98.7	54	62	58	14	15	15	78	86	81
	14. 98.1	98.9	.....	54	58	.....	14	14	.....	78	86	
	15. 98	98.5	99.3	50	52	56	14	14	15	79	85	78
	16. 97.9	98.7	99.1	52	54	62	14	15	15	77	86	80
	17. 97.9	98.8	99	54	60	76	14	15	15	77	86	81
	18. 98	98.9	98.9	56	58	56	14	14	16	77	85	81
	19. 98	98.7	99	52	54	58	14	15	15	78	79	80
	20. 98	99.1	98.7	50	56	62	14	15	15	77	85	81
	21. 97.9	98.8	99	50	56	60	14	15	15	78	85	80
	22. 98	98.7	99.2	50	56	60	14	15	15	77	85	82
	23. 98	98.9	99	54	54	56	14	14	14	78	86	82
	24. 98.1	.....	98.9	54	.....	62	14	.....	15	79	.....	79
	25. 97.8	98.6	98.8	52	56	56	14	16	15	78	83	81
	26. 97.9	98.9	99.2	52	52	60	14	15	14	78	84	81
	27. 98.2	98.9	98.8	54	54	58	14	15	14	77	86	80
	28. 97.9	98.9	98.8	50	54	58	14	15	15	77	85	79
	29. 97.9	98.8	99.2	52	56	60	14	14	16	75	86	89
	30. 97.8	99	99.3	54	54	62	14	14	15	77	86	80
	98	98.8	99	51	56.1	56.8	14.1	14.8	14.9	77.5	84.7	80.4

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
July 1848.	1. 97.9	99.1	98.9	48	54	58	14	15	15	79	86	82
	2. 98.1	98.3	98.9	58	52	56	14	15	14	78	87	82
	3. 98.2	99	99.1	52	56	64	13	13	15	78	84	81
	4. 98.1	98.6	98.5	52	54	78	13	15	15	76	79	79
	5. 98.3	98.9	98.5	60	54	58	14	15	15	75	84	79
	6. 98.1	99	99.1	52	52	58	14	14	14	78	85	81
	7. 97.9	98.9	99.1	52	56	58	14	14	15	78	83	81
	8. 98.1	99	98.5	51	54	72	14	15	14	78	84	81
	9. 98.2	.....	99.3	56	.....	58	14	.....	15	78	.....	82
	10. 98.2	98.9	99.1	52	54	58	14	16	15	77	85	80
	11. 97.8	98.7	99	50	56	54	14	14	14	77	85	80
	12. 98	.....	.....	50	.....	.....	14	.....	.....	77	.....	.....
	26. 97.9	99	99.4	54	56	58	14	15	15	77	85	80
	27. 98	98.9	98.7	54	56	58	14	15	15	77	85	80
	28. 98.2	99	98.9	54	56	56	15	15	15	79	85	82
	29. 98.2	98.4	98.9	54	50	52	14	15	15	79	85	81
	30. 98.1	98.9	98.5	54	50	54	14	13	15	78	83	81
	31. 98.1	99.2	99	52	58	58	14	14	15	78	85	80
	98	98.3	98.9	53	54.2	59.5	14	14.7	14.8	77.7	84.3	79.4
August 1848.	1. 97.8	99	98.7	52	54	56	14	15	15	78	85	80
	2. 97.8	.....	98.5	52	.....	76	13	.....	15	78	.....	79
	3. 98.3	98.7	98.7	54	54	54	14	15	14	78	86	80
	4. 98.1	98.7	98.6	54	52	54	15	15	14	79	82	81
	5. 98.1	99	98.9	56	52	56	14	15	15	78	85	80
	6. 97.8	99	99	52	54	58	13	14	15	76	85	81
	7. 98.2	99	99.6	56	58	66	14	15	15	78	86	81
	8. 98.1	99.1	99	56	54	60	14	16	15	79	85	80
	9. 98.2	.....	.....	54	.....	.....	15	.....	.....	79	.....	.....
	10. 98.3	98.9	98.7	66	54	58	15	15	15	77	83	80
	11. 97.9	99.1	99.2	54	54	58	14	15	16	77	86	81
	12. 98.1	99.3	99.1	54	56	58	14	15	15	79	86	82
	13. 98.2	98.9	98.9	56	54	60	14	14	15	79	86	83
	14. 98.2	99	99.6	56	58	62	14	15	15	80	85	82
	15. 98	99.2	98.8	56	58	62	14	15	16	79	86	80
	16. 98.2	.....	.....	56	.....	.....	14	.....	.....	79	.....	.....
	17. 98.2	99.7	99.7	58	60	58	14	14	14	79	84	81
	18. 98.1	99.2	99.1	54	58	58	15	14	15	79	86	79
	19. 98.1	99.3	99.2	54	56	56	14	15	15	79	86	81
	20. 98.2	99	.....	54	54	.....	14	15	.....	78	81	.....
	22. 98.2	99.1	99.5	54	56	66	14	16	15	80	87	82
	23. 98.1	.....	.....	56	.....	.....	14	.....	.....	78	.....	.....
	24. 98.1	99.4	99.4	60	60	60	14	16	15	77	86	82
	25. 98.1	99.4	98.8	56	56	54	14	15	15	79	86	82
	26. 98.2	99.3	99.2	54	66	60	14	16	15	79	87	82
	27. 98.1	99.1	99.2	52	60	56	13	15	15	78	86	79
	28. 98.1	99.4	99.6	56	60	66	14	15	15	78	86	82
	29. 98.2	.....	98.9	56	.....	70	14	.....	14	79	.....	80
	30. 98.2	.....	99.4	56	.....	66	14	.....	14	79	.....	82
	31. 98.2	99.1	99.4	58	60	66	14	15	14	80	87	82
	98.1	99.1	99.1	55.4	56.3	59.5	13.9	15	14.7	78.4	85.3	80.9

		Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
		6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
September 1848.	1.	98	99.2	99	52	56	64	14	15	16	78	87	81
	2.	98.1	99	99.2	54	52	60	14	15	16	78	88	81
	3.	98	99.3	99	52	54	60	14	14	14	79	88	84
	4.	98.1	99.6	99.4	52	62	60	14	14	15	80	87	82
	5.	98.2	99.4	99.4	56	66	64	14	15	16	79	87	80
	6.	98	.....	99.2	54	.....	64	14	.....	15	79	.....	81
	7.	98.2	99.6	99.6	54	60	62	14	16	15	78	88	82
	8.	98.5	99.5	99.2	56	60	58	14	15	15	79	88	86
	9.	98.3	99.5	99.6	56	60	66	15	15	15	83	89	84
	10.	98.3	99	99.3	56	56	66	15	16	15	80	89	82
	11.	98.3	97.9	99.2	56	60	66	14	15	15	80	89	82
	12.	97.9	99.2	99.3	52	58	60	14	15	14	80	88	83
	13.	98.1	.....	.....	54	.....	.....	14	.....	.....	79	.....	.....
	14.	98	99.3	99	56	60	62	14	15	15	78	86	81
	15.	98.5	99.2	98.9	54	56	72	14	15	16	79	85	81
	17.	98	99	98.9	54	54	66	14	15	15	76	85	82
	18.	98.3	99.4	99.9	54	58	74	14	15	16	79	84	82
	19.	98.5	98.8	99.3	58	56	70	14	15	14	79	80	81
	20.	98.3	98.9	98.7	58	54	66	14	15	16	80	84	82
	21.	98.3	99	98.8	58	52	56	14	15	16	81	86	82
	22.	98.1	98.7	99.2	52	52	60	14	15	16	81	86	82
	23.	98	98.9	.....	52	56	.....	14	16	.....	78	86	.....
	24.	98.5	98.7	99.1	62	56	62	14	15	15	80	86	80
	25.	98	99.3	99.1	52	56	56	14	16	15	78	85	82
	26.	98.2	99.2	98.8	54	52	56	14	15	15	78	85	80
	27.	98.1	.....	.....	52	.....	.....	14	.....	.....	77	.....	.....
	28.	98.3	98.8	99.3	54	56	58	14	16	15	75	85	80
	29.	98.5	99.2	99.3	54	58	60	14	15	15	78	86	82
	30.	98.2	98.8	99	52	58	66	14	16	15	79	85	82
		98.1	99.1	99.1	54.4	57.3	60.4	14	15	15.2	78.9	86.2	81.7
October 1848.	1.	98.3	98.8	98.8	56	56	66	14	15	16	79	86	83
	2.	98.2	99	98.7	52	56	60	14	14	15	79	82	80
	3.	98.2	99	.....	52	56	.....	14	15	.....	78	86	.....
	4.	98.4	99.3	99.2	60	56	60	15	15	15	79	87	84
	5.	98.5	.....	99.3	54	.....	72	14	.....	15	82	.....	83
	6.	98.1	99.3	99.1	50	56	58	14	16	15	80	87	82
	7.	98.3	99.2	99.4	54	54	60	15	15	15	80	87	80
	8.	97.9	99.1	98.8	52	58	58	14	16	15	78	84	80
	9.	98.1	99.4	99.4	54	56	60	14	15	15	76	87	81
	10.	97.9	99.2	98.7	54	52	58	15	15	15	80	84	81
	11.	98.3	99.5	99.9	54	58	60	14	16	15	79	87	81
	12.	98.1	99.4	99.3	54	58	64	15	15	16	79	86	80
	13.	98.1	99	99.1	56	58	62	14	16	15	79	87	78
	14.	98.3	99.3	.....	54	58	.....	14	16	.....	78	88	.....
	15.	98.2	98.9	99.3	56	58	66	14	14	16	78	86	82
	16.	97.9	98.8	98.6	54	52	58	14	14	15	80	80	78
	17.	98	99.1	99	52	54	60	14	16	15	77	86	80
	18.	98.5	.....	98.6	58	.....	58	15	.....	16	78	.....	80
	19.	98.1	98.9	99.2	56	58	62	15	15	16	78	85	82
	20.	98.1	98.9	98.7	58	58	64	14	15	16	79	80	79
	21.	98.4	98.6	98.9	54	52	62	15	15	16	77	86	82
	22.	98.3	.....	99.1	56	.....	58	14	.....	16	79	.....	80
	23.	98.2	98.8	98.9	52	52	56	14	15	15	79	82	80
	24.	98.4	99.1	98.4	56	54	60	14	15	15	77	83	79
	25.	98.5	.....	.....	52	.....	.....	14	.....	.....	77	.....	.....
	26.	98.2	99.3	99.3	58	56	66	14	15	15	76	86	82
	27.	98	99.1	98.8	54	56	58	14	14	15	77	86	81
	28.	98.1	99.1	99.1	52	56	62	14	15	16	78	87	83
	29.	98.4	99.5	.....	54	58	.....	14	15	.....	80	83	.....
	31.	98.3	98.8	98.8	52	52	60	14	15	15	78	77	79
		98.2	99.1	99	54.3	55.8	61	14.2	15	15.3	78.9	84.8	80.8

	Temp. under the tongue.			Pulse.			Respirations.			Temperature of room.		
	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.	6-7 A.M.	12-2 P.M.	9-11 P.M.
November 1848.	1. 98°2	99°3	99°	50	58	60	14	16	15	77°	85°	81°
	2. 98°1	99°	.....	52	56	.....	14	15	.....	78	82	.....
	3. 98°5	98°8	98°5	58	56	58	15	15	15	77	82	78
	4. 98°2	99°1	.....	50	58	.....	14	15	.....	77	84	.....
	5. 98°1	99°4	98°5	62	58	58	15	16	16	78	86	79
	6. 98°1	99°2	98°4	56	58	58	14	15	15	77	83	78
	7. 98	98°9	.....	58	56	.....	14	15	.....	77	83	.....
	8. 98°2	99°3	98°9	54	62	62	14	16	16	76	83	79
	9. 98°1	.....	.....	58	.....	.....	14	.....	.....	78	.....	.....
	98°1	99°1	98°6	55°3	57°7	59°2	14°2	15°4	15°4	77	83°5	79

Postscript to Dr. DAVY's Paper on the Temperature of Man.

Received May 8,—Read May 16, 1850.

The thermometer with which the preceding observations were made was broken immediately after my return to England, when travelling by railway, no special precaution having been taken in the packing of it, as by inclosing it in elastic horse-hair; and in consequence I had not the means at once of making further trials on temperature for the purpose of comparison. Recently, having had another thermometer constructed as delicate as that before used and divided with the same minuteness—each degree of FAHRENHEIT into ten parts—I have been enabled to continue the trials; as yet, however, only for one month, that of April, without interruption. They have been made thrice daily, at about the same hours as those recorded in my former paper. The results, under ordinary circumstances of health, exercise, &c., have accorded with those then obtained, the highest temperature having been found to be immediately on rising in the morning after the night's rest, and the lowest at night, just before retiring to rest. This accordance will probably be received in proof that the difference of results in the West Indies and in England has been mainly owing to difference of climate and the habits of life connected therewith; and apart from these, to no change in the individual, the subject of the trials.

May 4, 1850.

XXIII. *On the Oils produced by the Action of Sulphuric Acid upon various Classes of Vegetables.* By JOHN STENHOUSE, Esq., Ph.D., F.R.S.

Received March 28,—Read April 18, 1850.

NEARLY thirty years ago DÖBEREINER observed, when preparing formic acid by distilling a mixture of starch, peroxide of manganese and sulphuric acid, that the liquid which passed into the receiver contained a small quantity of oil which rendered it turbid. To this oil DÖBEREINER gave the somewhat fanciful name of “artificial oil of ants,” though the very limited quantity in which he was enabled to procure it prevented him from determining almost any of its properties.

My attention was first directed to the subject in 1840, when I found that the oxide of manganese was quite unnecessary, and that this oil could be readily prepared by operating on most vegetable substances with slightly diluted sulphuric acid. In this way I succeeded in procuring considerable quantities of the oil from wheaten and oaten flour, from saw-dust, bran, chaff, &c., and was thus enabled to subject it to a more detailed examination. The oil, when analysed, was found to have the formula $C_5 H_2 O_2$, or the triple of this, $C_{15} H_6 O_6$, presenting the remarkable circumstance of a volatile aromatic oil containing oxygen and hydrogen in the proportions to form water. This proved it to differ essentially from other known oils, all of which contain an excess of hydrogen.

Dr. FOWNES took up the subject in 1845, and made the interesting discovery, that when the oil was agitated with a considerable excess of aqueous ammonia and set aside for a few hours, it was converted into a bulky crystalline mass, becoming $C_{15} H_6 O_3 N_1$ by the absorption of one equivalent of nitrogen and the elimination of three equivalents of oxygen which had united with the hydrogen of the ammonia. To this compound Dr. FOWNES gave the name of furfuramide, and to the oil itself that of furfurol. Dr. FOWNES also made the still more important discovery, that when furfuramide is boiled for a short time with dilute potash lye, it is without any alteration of its per-centage composition, but merely by a new arrangement of its component elements converted into a crystalline base, furfurine, the formula of which is $C_{30} H_{12} O_6 N_2$.

Furfurol was also examined in 1848 by M. CAHOURS, who, in addition to confirming Dr. FOWNES's discoveries, observed that when a stream of sulphuretted hydrogen is passed through an alcoholic solution of furfuramide, the half of the oxygen in that body is removed and replaced by sulphur. This new compound, which he called thiofurfurol, precipitates as a crystalline powder and has the formula $C_{10} H_4 S_2 O_2$.

M. CAHOURS also found that when thiofurfurol is distilled it is entirely decomposed, producing a beautifully crystalline substance containing no sulphur. Its formula is $C_{18} H_8 O_4$, or some multiple of these numbers.

As furfurol, both from its composition and properties, occupies a somewhat isolated position in regard to other essential oils, it appeared to me not improbable that it would be found on more extended investigation not to stand really alone in nature, but to be one of a series of similar oils. This consideration induced me about six months ago to resume its examination, and, as will presently be seen, the expectation I had formed was not altogether without foundation. Before detailing these researches, however, I shall shortly state a few additional observations which I have recently made upon furfurol and some of its compounds.

Furfurol is most advantageously prepared by distilling one part of bran with rather more than half its weight of sulphuric acid diluted with two parts of water. I find, however, that furfurol may be also produced with muriatic acid, though in practice it is more advantageous to employ sulphuric acid, as it remains in the retort and does not distil over with the oil, as is the case with muriatic acid.

The arrangement for preparing furfurol on a considerable scale which I have found most suitable, is the following. About 32 lbs. of wheaten bran and 20 lbs. of sulphuric acid diluted with twice its bulk of water, were introduced into a large three-necked WOLF's-bottle made of salt-glazed earthenware. These bottles are usually employed as condensers in the manufacture of muriatic and nitric acids, and are capable of containing from twenty to thirty gallons each. A leaden pipe connected with a tolerably large steam-boiler is passed through a perforated cork to near the bottom of the stone-ware bottle, from the top of which, on the opposite side, a second pipe is carried into the worm of a condensing apparatus, which is kept cool by means of a plentiful supply of cold water. The steam from the boiler is then passed through the mixture of the acid and the bran, which soon becomes hot and then boils, when a weak aqueous solution of furfurol passes over into the condensing apparatus and is collected in the usual way: the whole of the oil usually comes over in from 16 to 18 hours. This weak liquid is pretty strongly acid, and requires to be exactly neutralized with pounded chalk, and to be rectified till about the half of it has distilled over. It is important to avoid adding an excess of chalk, and rather to leave the liquid slightly acid, as an excess of chalk sets free the ammonia present in the solution, which, combining with the furfurol, oxidizes it, and thus greatly diminishes the amount which would otherwise be obtained. The first portion only of the liquid which distils over is preserved, as that which remains in the still contains scarcely any oil. The now somewhat stronger solution of the oil is then supersaturated with common salt and again cautiously rectified. The first portions of the liquid which come over yield a considerable amount of oil, and by repeatedly saturating the weaker solutions with salt and rectifying, the whole of the oil they contain may be pretty readily obtained. The 32 lbs. of bran yielded from 12 to 13 ozs. of furfurol. I have invariably found

that crude furfurol always contains a considerable quantity of acetone, a circumstance which appears to have escaped the notice of preceding experimenters.

In addition to the substances which had been previously employed for preparing furfurol, I may mention that I have obtained it from oil-cake, from cocoa-nut husk, and from the raspings of mahogany. The two first substances, from their cheapness and the large quantity of oil which they yield, are very well fitted for this purpose. The furfurol from mahogany, though smaller in quantity, is pretty free from resin, and is therefore more readily purified than that from bran or oil-cake.

Crude furfurol, from whatever source it is prepared, always contains a quantity of another essential oil, which has a much higher boiling-point and does not form a crystallizable amide. This second oil is exceedingly oxidizable, and every time it is distilled a considerable portion of it is changed into a brownish resin, which instantly strikes a deep red colour when mixed with a few drops of cold muriatic, nitric or sulphuric acids. In a previous paper I mentioned this reaction as characteristic of furfurol, and in this statement I have been followed by Dr. FOWNES. It is a mistake, however, as furfurol never yields this deep red colour with acids when it has been freed from this accompanying oil, which, as it appears to be invariably formed along with furfurol, I shall call meta-furfurol.

Furfurol may be pretty readily freed from this oil by being repeatedly rectified with water; the meta-furfurol, as it is much less volatile, remains chiefly in the retort, where it is rapidly oxidized. Two, or at most three rectifications, are therefore sufficient to render furfurol perfectly free from meta-furfurol. The absence of meta-furfurol may be easily ascertained by boiling an aqueous solution of furfurol with an excess of lime for a few minutes. The furfurol is immediately oxidized, and the solution acquires a deep yellow colour. If this solution is then treated with an excess of muriatic or sulphuric acids, not the slightest reddening is produced if the furfurol is free from meta-furfurol, but if even a trace of this latter oil is present, the characteristic deep red colour immediately appears. When pure furfurol is added to strong muriatic or sulphuric acid in the cold, it instantly changes to a brownish black colour, being rapidly oxidized, but not the slightest reddening is visible. Meta-furfurol is also much less soluble in water than furfurol. It also dissolves with difficulty in aqueous ammonia, with which it forms no crystallizable amide, but is rapidly changed into a brownish amorphous resin. When meta-furfurol is digested with strong nitric acid, it is changed into a nitrogenated crystallizable acid, which is either oxypicric acid, or a closely analogous compound. It yields chloropicrine when it is treated with either muriatic acid or hypochlorite of lime. Furfurol, on the contrary, when digested with nitric acid, is wholly converted into oxalic acid. Crude furfurol made from bran contains a good deal of meta-furfurol, but the crude furfurol from mahogany and other hard woods is comparatively free from meta-furfurol.

Furfurol stains the skin of a deep yellow colour, but if the part moistened with it is also touched with a few drops of aniline it becomes of a bright red colour. The

same effect is also produced when paper, white silk, linen or cotton cloth is similarly treated. The red colour begins to appear in the course of a few minutes and remains for some days, after which it changes to a brownish yellow. I regard this coloration as an effect of mutual oxidation, for I have failed in procuring any crystalline compound similar to furfuramide, either with aniline or with some others of the volatile alkaloids.

Double Chloride of Furfurine and Platinum.

Dr. FOWNES, who first prepared this salt, states that a solution of hydrochlorate of furfurine, when treated with a slight excess of bichloride of platinum, forms a nearly insoluble bright yellow precipitate. This is true only when the double salt is produced by mixing cold aqueous solutions. When however chloride of platinum is poured into a hot solution of muriate of furfurine in weak spirits, the same salt is slowly deposited on the cooling of the liquid in bright yellow needles, often an inch in length, and closely resembling carbazotate of potash in appearance.

I. 0.4265 grm. salt prepared in the way just described and dried *in vacuo*, gave 0.089 platinum = 20.86 per cent. platinum.

II. 0.326 grm. salt prepared in the way just described and dried *in vacuo*, gave 0.0670 platinum = 20.55 per cent. platinum.

The calculated quantity for the formula $C_{30}H_{12}N_2O_6 + HCl + PtCl$, is 20.82 platinum per cent. Dr. FOWNES found 20.45. There can be no doubt, therefore, notwithstanding the difference in their mode of preparation and crystalline state, that both salts are identical.

Nitrate of Furfurine.

Dr. FOWNES also analysed nitrate of furfurine crystallized from an aqueous solution. It then forms irregular long acicular crystals arranged in stars. From alcohol it is deposited in large very regular rhombic prisms, which possess great lustre, and may be readily obtained nearly an inch in length. If the spirituous solution out of which the salt has crystallized is very strong, its crystals, which are at first perfectly transparent, on being kept for some time in a dry atmosphere become quite opaque, but if they are crystallized out of dilute spirits they retain their transparency.

0.2905 grm. salt crystallized out of spirits and dried *in vacuo*, gave 0.580 carbonic acid and 0.109 water.

	Found numbers.
C 54.35	54.45
H 3.93	4.16

The formula of this salt is $C_{30}H_{12}N_2O_6 + NO_5 + HO$.

It is plain therefore that the nitrate, whether it is crystallized out of water or weak spirits, does not vary in composition after it has been dried *in vacuo*.

Fucusol.

It has been satisfactorily ascertained by various experimenters that furfurol is not produced by the action of acids on either the amylaceous or saccharine portions of the vegetables which yield it. Neither do the lignine, the gluten or the other nitrogenous principles of plants, at all contribute to its formation. The source of furfurol requires to be referred therefore to some other very generally diffused proximate principle. Dr. FOWNES has thrown out the conjecture, that the substance which yields furfurol is the *matière incrustante* of M. PAYEN, viz. the matter with which the interior of the cells of plants is lined. This is a hypothesis which I feel disposed to regard as exceedingly probable, though it must be confessed that the *matière incrustante* is not a simple proximate principle, but consists, according to M. PAYEN, of four kindred substances, no one of which the present state of our knowledge enables us with any great degree of certainty to prepare absolutely pure.

Now as it appeared very probable that the *matière incrustante* of the different great classes of plants would be found on examination to be analogous but not identical, I thought it likely that the oils derivable from them would also prove not identical with furfurol, though probably very analogous to it in their nature and properties. The Algæ therefore, as possessing a structure which differs very widely from ordinary herbaceous plants, were selected in the first instance as a very good test of the truth of this hypothesis. A quantity of the commonest sea-weeds, consisting chiefly of *Fucus nodosus*, *F. vesiculosus*, *F. serratus*, &c., were cut into pieces and introduced along with a good deal of sulphuric acid diluted with two parts of water, into the apparatus described in a preceding part of this paper. Steam was then passed through the mixture during sixteen to eighteen hours, so long indeed as the liquid which distilled over appeared to contain any considerable amount of oil. The acid liquor which collected in the receiver was nearly neutralized with pounded chalk, and the oil separated from it exactly in the same way as with furfurol.

The crude oil from Fuci, which I shall call fucusol, always contained a considerable amount of acetone, which required to be removed by washing it with water, carefully rectifying it at a low temperature, and rejecting the first portions of the oil which distilled over. I may mention in passing, that I have invariably found acetone to be a constant product, and that to a considerable extent, of the action of sulphuric acid upon vegetable substances. Crude fucusol also contains a quantity of meta-furfurol, or at any rate of a very similar oil, from which it requires to be freed by being repeatedly rectified along with water, precisely in the same way as furfurol. The sea-weeds yielded only about a fourth part of the oil which a similar quantity of bran would have done.

When dried by standing over fused chloride of calcium and then rectified, fucusol possesses the following properties. When newly distilled it is nearly colourless, but in a few days, especially if exposed to the light, it becomes brownish yellow, and in the course of a few weeks of a deep brown colour. If the fucusol is not quite free

from meta-furfurol it colours still more rapidly, and in the course of a few days becomes perfectly black; pure fucusol may however be kept in hermetically sealed vessels for any length of time without change. Its specific gravity at $13\frac{1}{2}^{\circ}\text{C.}$ is 1.150. I found that of furfurol at the same temperature 1.1636. Dr. FOWNES makes it 1.1648 at 60°FAHR. When heated in a glass retort containing some thin slips of copper, fucusol boils regularly and uniformly between 171° and 172°C. As the boiling proceeds, the oil grows coloured, and a small portion of it is destroyed by every distillation, being converted into a dark-coloured resin which remains in the retort. I found the boiling-point of furfurol from bran to be 166°C. , while Messrs. FOWNES and CAHOURS found it only to be $162\frac{1}{2}^{\circ}\text{C.}$ Neither of these gentlemen make any mention of the acetone which is always present in crude furfurol; I do not however affirm that the oil examined by these chemists contained acetone, though, judging from the lowness of its boiling-point, I think this by no means improbable.

Fucusol very closely resembles furfurol both in its taste and smell, though the odour of fucusol is much fainter and more agreeable. Fucusol requires 14 parts by weight of water at 13°C. to dissolve it, while furfurol dissolves in 11 parts of water at the same temperature. Furfurol dissolves in 9 times its weight of pretty concentrated liquor ammoniæ at $13\frac{1}{2}^{\circ}\text{C.}$, while fucusol requires 12 times its weight of the same liquid for its solution. The difference therefore between the oils in regard to solubility is considerable. Fucusol also shows much less stability, and is therefore more readily decomposed than furfurol. With muriatic acid, fucusol strikes a pale green colour, which on standing becomes greenish black. Nitric acid gives it a pale yellow colour, sulphuric acid a greenish brown, which in time becomes bluish black. Solution of potash turns it first yellow, then pale red, and lastly dark red. Lime and soda produce similar results. If however the fucusol contains any meta-furfurol, it instantly strikes a bright red colour with either muriatic, nitric or sulphuric acids. Fucusol stains the skin of a deep yellow colour, which is tolerably persistent. If these yellow spots are moistened with aniline, they immediately become bright red, exhibiting the same reaction as furfurol. Pure fucusol when dried was analysed.

I. 0.2605 grm. oil gave 0.594 carbonic acid and 0.104 water.

II. 0.254 grm. oil gave 0.583 carbonic acid and 0.105 water.

III. 0.228 grm. oil gave 0.521 carbonic acid and 0.092 water.

Calculated numbers.			Found numbers.		
			I.	II.	III.
15 C	1125	62.50	62.19	62.59	62.32
6 H	75	4.17	4.43	4.59	4.48
6 O	600	33.33	33.38	32.82	33.20
	1800	100.00	100.00	100.00	100.00

It is plain therefore, from the results of these analyses, that the formula of fucusol is $\text{C}_{15}\text{H}_6\text{O}_6$, and consequently that furfurol and fucusol are isomeric compounds.

Fucusamide.

When fucusol is intimately mixed with eight or nine times its bulk of pretty concentrated aqua ammoniæ, the oil and ammonia combine to form a slightly yellow crystalline mass. As fucusol is less soluble in liquor ammoniæ than furfural, it requires a greater quantity of ammonia, and both liquids must be brought thoroughly into contact, otherwise the fucusol is apt to be acted on chiefly at the surface, while the interior of the mass contains a portion of nearly unaltered oil. The amide, which I shall call fucusamide, may be readily obtained in pretty long needles radiating from a centre by crystallizing it out of hot spirits of wine, in which it is very soluble. In appearance it closely resembles furfuramide, but is a much less stable compound.

I. 0.413 grm. amide dried *in vacuo*, gave 1.02 carbonic acid and 0.174 water.

II. 0.332 grm. amide dried *in vacuo*, gave 0.809 carbonic acid and 0.138 water.

III. 0.357 grm. amide dried *in vacuo*, gave 0.884 carbonic acid and 0.152 water.

0.402 grm. amide dried *in vacuo* by WILL's method, gave 0.655 double chloride of platinum and ammonia=10.23 per cent. nitrogen.

	Calculated numbers.		I.	II.	III.
15 C	1125	67.17	67.35	66.46	67.53
6 H	75	4.47	4.67	4.61	4.72
3 O	300	17.91	17.75	18.70	17.52
1 N	175	10.45	10.23	10.23	10.23
	1675	100.00	100.00	100.00	100.00

The formula of fucusamide is therefore $C_{15} H_6 O_3 N_1$, being identical with that of furfuramide.

Thiofucusol.

M. CAHOURS observed, that when furfuramide is dissolved in spirits of wine, and a current of sulphuretted hydrogen sent through the solution, a whitish granular precipitate falls, which consists of a compound in which the half of the oxygen in furfuramide is replaced by sulphur. On passing a current of sulphuretted hydrogen through a cold alcoholic solution of fucusamide, a corresponding compound was formed, which closely resembles thiofurfural in appearance and properties.

0.477 grm. thiofucusol dried *in vacuo*, gave 0.929 carbonic acid and 0.170 water.

0.6045 grm. thiofucusol dried *in vacuo*, gave 1.26 sulphate of baryta=28.65 sulphur.

	Calculated numbers.		Found numbers.
10 C	705	53.58	53.12
4 H	50	3.58	3.95
2 S	400	28.58	28.65
2 O	200	14.26	14.28
	1355	100.00	100.00

MDCCCL.

3 P

Pyrofucusol.

When thiofurfurol is destructively distilled it is decomposed with the formation of a curious substance called pyrofurfurol, which crystallizes in long needles and contains no sulphur. M. CAHOURS's formula for it is $C_{18} H_8 O_4$. Thiofucusol, when distilled, yields a similar compound, which I shall call pyrofucusol. It also crystallizes in long needles, and has probably the same composition as pyrofurfurol, though from the very small quantity at my disposal I was unable to ascertain this by analysis.

Fucusine.

When pure fucusamide, which should be nearly colourless, having only a slightly yellowish shade, is boiled for 20 minutes or half an hour with moderately strong soda or potash lye, no ammonia is evolved, and the amide is changed into a light brownish-coloured oil, which solidifies on the cooling of the liquid. It consists of a salifiable base, which I shall call fucusine, combined with a quantity of a brownish resin. This crude fucusine, when separated from the lye in which it has been boiled, is always soft, even at low temperatures, and does not exhibit the least approach to crystallization. At the temperature of $10^{\circ} C$. it is exceedingly tenacious, and may be easily drawn into threads, which resemble those of half-dried molasses. If we attempt to separate fucusine from adhering resin by boiling it with water and filtering, we find, on the cooling of the solution, that a yellowish amorphous resin is deposited on the sides and bottom of the vessel. This method therefore, by which furfurine is so readily purified and obtained in a crystalline state, does not at all succeed with fucusine. Though I made many attempts, I was equally unsuccessful in crystallizing crude fucusine either from alcoholic or etherial solutions. If the fucusamide which has been employed in the preparation of fucusine is so impure as to have a brownish colour, it is next to impossible to extract any pure fucusine from it. In this respect therefore fucusine differs very considerably from furfurine, which, even when very impure, solidifies on cooling to a hard crystalline mass; and if it is digested with a little animal charcoal and crystallized two or three times out of boiling water, it is deposited on the cooling of its solution in long slender colourless needles. Fucusine, on the other hand, so long as it is mixed with a little resinous matter, does not crystallize at all, and even when perfectly pure does not crystallize nearly so readily as the analogous base.

The way in which I succeeded in purifying fucusine, was by preparing some of its salts, which crystallize pretty readily, even from impure solutions. The salt best adapted for this purpose is the nitrate, and the mode of proceeding was the following. The crude fucusine was digested with a very slight excess of dilute nitric acid at a heat little higher than was necessary to melt it. The crude fucusine was constantly stirred with a spatula, so as to bring every portion of it into contact with the acid liquid. The mixture was then allowed to cool for a few minutes till the resinous matter had solidified, when the liquid portion was poured off into a second basin, where it soon deposited a quantity of hard shining crystals. By repeatedly digesting

the crude fucusine with the acid mother-liquors out of which the crystals of nitrate had been deposited, successive crops of crystals may be readily obtained. These are still further purified by being repeatedly crystallized out of hot water, and they may be easily obtained in large shining rhombic prisms when deposited from an alcoholic solution. By dissolving the colourless crystals of pure nitrate of fucusine in water, and slightly supersaturating the solution with ammonia, fucusine gradually subsides in white, short flattish prisms forming small stars.

When pure fucusine is dissolved in boiling water, the solution, so soon as it begins to cool, grows turbid, and in the course of a few hours the fucusine is deposited in short flattish prisms arranged in fan-shaped figures on the sides and bottom of the vessel. Its mode of crystallizing strongly contrasts with that of furfurine, which, so soon as its solution begins to cool, forms long slender needles which in a short time fill the whole of the liquid. Furfurine may be obtained from pure furfuramide with little more than a trace of adhering resin, but even from nearly colourless fucusamide I was seldom able to procure much more than two-thirds of fucusine, the remainder being changed into a dark-coloured tenacious resin.

The cold aqueous solution of fucusine is distinctly alkaline to test-paper, and its alcoholic solution, as might have been expected, is still more strongly so. Fucusine and furfurine are nearly equally soluble in boiling water, but fucusine dissolves in 2·400 parts by weight of water at 8° C., while furfurine requires 4·800, or exactly twice the quantity at the same temperature. This is one reason that while a hot aqueous solution of furfurine, on cooling, is filled with long slender crystals of that base, a much smaller portion of fucusine crystallizes out, as twice as much of it is retained in the cold solution. Fucusine is however considerably less soluble in dilute spirits, at ordinary temperatures, than furfurine.

I. 0·393 grm. fucusine dried *in vacuo*, gave 0·97 carbonic acid and 0·162 water.

II. 0·457 grm. fucusine dried *in vacuo*, gave by WILL's process 0·75 ammonio-chloride of platinum=10·30 nitrogen.

Calculated numbers.			Found numbers.
30 C	2250·0	67·17	67·30
12 H	149·7	4·47	4·58
2 N	350·4	10·45	10·30
6 O	600·0	17·91	17·82
	3350·0	100·00	100·00

It is plain from the result of this analysis, that fucusine and furfurine are also isomeric compounds.

Nitrate of Fucusine.

This is one of the salts of fucusine which crystallizes most readily. I have already detailed the mode of preparing and purifying it, and shall not therefore repeat it again. When crystallized out of a hot aqueous solution, it forms long prisms tapering towards their extremities, and united by their broad ends so as to form large stars. But when crystallized out of spirits of wine, it forms large rhombic prisms of great regularity of structure and adamantine lustre. When deposited from strong spirits of wine, these

crystals become opaque when dried, but when crystallized out of weak spirits, they retain their transparency. When dried under the air-pump and subjected to analysis, the salt was found to have the same formula as the corresponding salt of furfurine, viz. $C_{30} H_{12} N_2 O_6 + NO_5 + HO$.

0.488 grm. salt gave 0.972 carbonic acid and 0.1875 water.

	Calculated numbers.	Found numbers.
C	54.30	54.32
H	3.99	4.26

When the nitrate of fucusine is heated in the water-bath to $100^\circ C.$, it soon becomes coloured and decomposes.

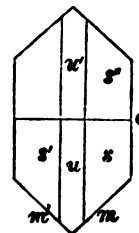
Through the kindness of Professor W. H. MILLER of Cambridge, which I have often formerly experienced, I am enabled to subjoin the annexed figures and measurements of the crystals of the nitrates of fucusine and furfurine.

Nitrate of Fucusine.

Prismatic:—The symbols of the simple forms are,— $a\ 100$, $u\ 011$, $m\ 110$, $s\ 111$.

The angles between normals to the faces are,—

uu'	$64^\circ\ 0'$
ma	$47\ 51$
mm'	$84\ 18$
sa	$68\ 6$
su	$21\ 54$
ss'	$43\ 48$
ss''	$60\ 42$
$s's''$	$71\ 0$



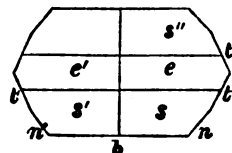
Cleavage:— a , very perfect; u , s , less perfect.

Nitrate of Furfurine.

Prismatic:—The symbols of the simple forms are,— $a\ 100$, $b\ 010$, $e\ 101$, $t\ 310$, $n\ 320$, $s\ 111$: a truncates the edge tt' .

The angles between normals to the faces are,—

ea	$70^\circ\ 40'$
ee'	$38\ 40$
nb	$47\ 50$
tb	$65\ 40$
ab	$90\ 0$
nn'	$84\ 20$
tt'	$48\ 40$
sa	$72\ 8$
ss'	$35\ 44$
sb	$67\ 39$
ss''	$44\ 42$
$s's''$	$58\ 44$



Cleavage:— b , very perfect; a , t , less perfect.

Muriate of Fucusine.

Muriate of fucusine is an extremely soluble salt, which crystallizes, when very concentrated, in short slender needles arranged in stars.

The Double Platinum Salt.

When bichloride of platinum is added to a cold aqueous solution of hydrochlorate of fucusine, a crystalline yellow precipitate immediately subsides. But if the solutions of the two salts are hot, and especially if some spirits of wine are added to the mixture, the double platinum salt is slowly deposited in large broad four-sided prisms. These prisms are very thin, having two broad sides and two very narrow ones. They are usually united together at the one extremity, while the other is square and regular. The double hydrochlorate of fucusine and platinum does not at all resemble in appearance the corresponding salt of furfurine, which, as formerly stated when crystallized out of weak spirits, forms long needle-shaped crystals like those of carbazotate of potash.

0.3733 grm. salt dried *in vacuo*, gave 0.518 carbonic acid and 0.109 HO.

0.6595 grm. salt dried *in vacuo*, gave 0.650 chloride of platinum and ammonia = 0.4085 nitrogen.

0.640 grm. salt dried *in vacuo*, gave 0.580 chloride of silver = 0.1434 CL.

I. 0.416 grm. salt gave 0.086 platinum = 20.67 per cent.

II. 0.5025 grm. salt gave 0.1035 platinum = 20.58 per cent.

III. 0.409 grm. salt gave 0.840 platinum = 20.53 per cent.

	Calculated numbers.		Found numbers.
30 C	2250.0	37.97	37.84
13 H	162.5	2.74	3.21
6 O	600.0	10.12	9.70
2 N	350.0	5.90	6.18
3 Cl	1329.0	22.45	22.40
Pt	1233.5	20.82	20.67
	5925.0	100.00	100.00

The formula of the double platinum salt therefore is $C_{30} H_{12} N_2 O_6 + HCl + PtCl_2$.

The Acid Oxalate of Fucusine.

This salt may be pretty readily prepared from crude fucusine by digesting it with an excess of oxalic acid. The hot filtered solution deposits, on cooling, the acid oxalate in long needle-shaped crystals arranged in stars. These crystals are usually coloured at first, but by repeated digestions with animal charcoal they are rendered colourless, when they have a silky lustre. They are not very soluble in cold water, but readily dissolve in boiling water and in hot spirits. Their solution is distinctly acid to test-paper.

0·3155 grm. salt dried *in vacuo*, gave 0·664 carbonic acid and 0·120 water.

0·336 grm. salt dried *in vacuo*, gave 0·419 double chloride of Pt and ammonia.

Calculated numbers.		Found numbers.
C	34 57·01	57·08
H	14 4·06	4·22
N	2 7·74	7·82
O	14 31·19	30·88
100·00		100·00

The formula of this salt therefore is $C_{30}H_{12}N_2O_6 + 2C_2O_3 + 2HO$. It is the binoxalate of fucusine with two equivalents of water. The neutral oxalate is much more soluble than the acid salt, but the crystalline form of both salts is the same.

The perfect isomerism which subsists between furfurol and fucusol, extending as it does to the products of their decomposition, is certainly not a little astonishing, and may perhaps induce some chemists still to regard them as identical substances. I was, in fact, for a long time inclined to the same opinion, and it was only after a careful comparative examination of both oils, and especially of their respective bases, that I was led to conclude that they are only very analogous, but not identical compounds.

Oil from Moss.

A quantity of common Sphagnum was digested in a distilling apparatus with dilute sulphuric acid, exactly in the way already so fully described. It yielded a considerable quantity of an oil, which, so far as I could judge, is identical with fucusol. It formed amide with ammonia, which, when it was boiled with an alkaline lye, yielded a similar difficultly crystallizable base, whose double platinum salt crystallized in the same thin flat prisms as those of fucusine.

Oil from Lichens.

A quantity of *Lichen Islandicum*, along with several species of *Usnea*, *Ramalinia fraxinea*, &c., were also digested with sulphuric acid. They yielded an oil which appeared to be identical with fucusol, judging from its characters and those of its amide, base and platinum salt.

Oil from Ferns.

The common fern, *Pteris aquilina*, when digested with sulphuric acid, also yielded an oil which formed an amide and a base, crystallizing readily in long slender needles, closely resembling those of furfurine. I felt at first much inclined to regard this oil as identical with furfurol, but as the double platinum salt of its base does not crystallize in the same form as the corresponding salt of furfurine, but in broad flat prisms, I strongly suspect that it is different from both fucusol and furfurol.

The results of the preceding investigation, imperfect as they confessedly are, seem to me to indicate some curious botanical relations; for it appears highly probable that the *matière incrustante*, or some such principle, is the same in all phanerogamous

plants, as it yields an identical product of decomposition, viz. furfurol when it is digested with sulphuric or muriatic acids.

The *matière incrustante* in Fuci, on the other hand, though analogous, appears to be not identical with the corresponding principle in phanerogamous plants, as it yields fucosol instead of furfurol; and this seems also to be the case with the *matière incrustante* of mosses and lichens, both of which families approximate much more closely in their botanical structure to the Algæ than to ordinary phanerogamous plants. As might almost have been expected, therefore, both mosses and lichens appear to yield fucosol, or at any rate an exceedingly similar oil, which is certainly not furfurol. Ferns, on the contrary, whose woody structure differs from that of either mosses, algæ, or lichens, and approaches pretty closely to that of ordinary phanerogamous plants, appear to yield an oil with properties intermediate between those of furfurol and fucosol.

NOTE received September 4, 1850, from Professor MILLER of Cambridge.

I consider it very probable that the crystals of nitrate of fucusine do not belong to the prismatic system, but are twin crystals of the oblique system. The faces of the form *s* are however too imperfect to settle this point.

The angles between normals to the faces are,—

$$\begin{array}{l} ma \quad 47^{\circ} 52' \\ mm' \quad 84 \quad 16 \end{array}$$

I have re-examined the crystals with all possible care, but cannot pretend to correct the angles which the faces of the forms *s*, *u* make with each other, and with the faces of the forms *a*, *m*.

Corrected angles between the normals to the faces of nitrate of furfurine (*not* from solution in alcohol) are,—

$$\begin{array}{l} ea \quad 71^{\circ} 5' \\ ee' \quad 37 \quad 50 \\ nb \quad 47 \quad 54 \\ tb \quad 65 \quad 41 \\ ab \quad 90 \quad 0 \\ nn' \quad 84 \quad 12 \\ tt' \quad 48 \quad 18 \\ sa \quad 72 \quad 44 \\ ss' \quad 34 \quad 32 \\ sb \quad 66 \quad 16 \\ ss'' \quad 47 \quad 28 \\ s's'' \quad 60 \quad 0 \end{array}$$

The values of the angles between the faces of the form *s* are very uncertain.

Opake Crystals of Nitrate of Furfurine.

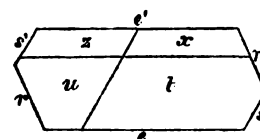
Crystals obtained from a solution in alcohol, which effloresced readily, and became in consequence opake.

These crystals belong to the anorthic system.

The symbols of the simple forms are,— $s\ 100$, $r\ 010$, $x\ 001$, $u\ 011$, $z\ 101$, $e\ 110$, $t\ 111$.

The angles between normals to the faces are,—

se	$58^{\circ} 50'$
re	$65\ 50$
sr'	$55\ 20$
xs	$76\ 50$
zx	$57\ 17$
zs'	$45\ 53$
te	$47\ 58$
xt	$51\ 14$
xe'	$80\ 48$
ur	$52\ 49$
ux	$60\ 21$
xr'	$66\ 50$
us'	$69\ 57$
tu	$55\ 31$
st	$54\ 32$
ze'	$54\ 43$
uz	$49\ 40$
eu	$75\ 37$



XXIV. *On the Development and Homologies of the Molar Teeth of the Wart-Hogs (Phacochærus), with Illustrations of a System of Notation for the Teeth in the Class MAMMALIA.* By Professor OWEN, F.R.S. &c.

Received November 12, 1849,—Read February 7, 1850.

IN a paper by EVERARD HOME, Esq., read before the Royal Society, May 30, 1799, some observations were communicated upon the form, structure and succession of the teeth of the Wart-Hogs of Africa, now included in the genus of the Hog-family called *Phacochærus*, but noticed in that paper as a single species under the name of *Sus Æthiopicus*. The observations are illustrated by two plates. The first (tab. xviii.) gives “a side view of the skull of the *Sus Æthiopicus* (half the natural size), to show the situation and appearance of the large grinder, and the remains of the alveoli belonging to the fangs of the preceding one*.” The second (tab. xix.) gives a “side view of the skull of the young *Sus Æthiopicus*, to show the mode in which the grinders come forward as the large one increases in size†.” This plate includes also a side view and a transverse section of the crown of the large full-grown grinding tooth.

The conclusions drawn from the facts given are, that the *Sus Æthiopicus* resembles the Elephant “in the whole number of grinding teeth belonging to each side of the jaw being confined in a case of bone, so as to form one large grinding surface, and the teeth being pushed forward from behind, instead of a second set being formed immediately under the fangs of the first, as in other animals; which are peculiarities not met with in any teeth hitherto described, except those of the Elephant‡.” The grinding teeth of the *Sus Æthiopicus* are described to be “four in number on each side of the jaw”§; . . . the fourth or last large tooth is considered to be a second set of teeth, which, as it advances forwards, pushes the other teeth before it; . . . “the most anterior of these, as soon as its body is worn away, has its fangs removed by absorption and drops out: the same thing takes place with the second and third; and, in this way, room is made for the large one to supply the place of all the others||.” The mode in which they succeed one another is stated to be illustrated by the side view of the jaw given in tab. xix., in which the fangs of the different teeth are exposed.

I have shown in my ‘Odontography’¶, that the facts detailed in HOME’s paper were insufficient to enable him to explain all the necessary circumstances respecting the curious mode of dentition of the Wart-Hogs; that other stages of dentition, unknown to that author, had demonstrated a second set of teeth formed under the fangs of some

* Philosophical Transactions, 1799, p. 256.

§ Ibid. p. 250.

† Ibid. p. 257.

|| Ibid. p. 250.

‡ Ibid. p. 247.

¶ Vol. i. p. 554.

of the first set, or above them in the upper jaw; and also that the subsequent shedding of the teeth in advance of the last large grinder was not in the order in which they are pushed out in the Elephant, the Wart-Hogs deviating very remarkably from that and all other quadrupeds in this respect.

In the course of subsequent researches and comparisons, I have determined the original specimens in the British Museum and that of the Royal College of Surgeons, which were drawn and engraved to illustrate HOME's paper, by which I have ascertained that the drawings were taken from two distinct species of *Phacocoerus*; and I have been able to detect certain inaccuracies in the reduced figures in the engravings, which give countenance, not afforded by the specimens themselves, to the ideas of the mode of succession of the teeth described in HOME's paper. I propose, therefore, to give a more precise description of the subjects of the beautiful engravings, tab. xviii. and xix. of the Philosophical Transactions for 1799, and to add the additional facts and illustrations of the peculiarities of the dentition characteristic of the two species of Wart-Hog, and which determine the true number, kinds and succession of the grinding-teeth in both species.

Tab. xvii. (Philosophical Transactions, 1799) gives a view of the skull of an old *Phacocoerus Eliani*, VAN DER HOEVEN, the common species of Nubia, Abyssinia, Senegal and Cordofan, and sometimes called the North African Wart-Hog. It is well characterized by having, when fully grown, six functional incisors in the under jaw and two incisors (*i. l.*) in the upper jaw, together with forms and proportions of the other teeth, which will be subsequently adverted to. The characteristic incisors are sufficiently indicated in the figure; the large posterior grinders are alone retained in the molar series of both jaws.

Tab. xix. fig. 1 (Philosophical Transactions, 1799) gives a view of the cranium of a younger individual of the *Phac. Pallasii*, VAN DER HOEVEN, the Wart-Hog most common, though not peculiar to the Cape and the Guinea coast districts. The molar teeth which are exposed in this figure are, taking them from before backwards, the last premolar, the symbol of which is *p* 4; the first true molar, *m* 1; the second true molar, *m* 2; and the last true molar, *m* 3.

The teeth are drawn somewhat reduced in size, but not in a just proportion to the reduction of the size of the cranium and of the upper tusks; nor are the relative lengths of the crown and fangs correctly given. The crown of the first true molar, *e. g.*, is represented of the same length as that of the fourth premolar which precedes it, and nearly of the same length as that of the second true molar, whereas in the original specimen it is much shorter in consequence of having been longer in use. Had the differences which these teeth actually show in the extent of the abrasion of their respective crowns been appreciated and duly considered, it might have excited the suspicion that the second tooth, with an almost exhausted crown and much-absorbed fangs, would be shed before the first tooth, the summit of whose long, obtuse and cement-covered crown had only recently been subject to the wear of mastication.

The grinder, which is the subject of figs. 2 and 3, tab. xix., is the last molar from the right side, lower jaw, of the *Phac. Æliani*, of the natural size.

To determine whether any successional teeth were developed above or beneath the fangs of pre-existing teeth destined to be displaced by such development, in other words, whether a true deciduous series and a premolar series of teeth existed in the Wart-Hogs, required an examination of the jaws of an individual younger than the youngest specimen examined and figured by HOME.

The subject of Plate XXXIII. fig. 1 of the present communication is of the required immaturity, and, with the other specimens to be described, supplies those links in the series which were wanting for the explanation of the entire course of the truly remarkable dentition of the genus *Phacochærus*.

Fig. 1 shows a side view of the teeth in the young *Phac. Æliani*; the grinding surface of the molar teeth in use is given, from the upper jaw in fig. 2, and from the under jaw in fig. 3. These teeth include all the milk-molars which are developed, together with the first permanent true molar. The milk-molars are 3—3 in number in the upper jaw, and 2—2 in the lower jaw. The first true molar, *m* 1, is also fully developed and in use in both jaws. The summit of the second true molar (*m* 2) is just appearing above the socket.

The length of the skull exhibiting this instructive phase of dentition is 10 inches.

The milk-molars answer to the teeth of the typical dentition symbolized by *d* 2, *d* 3, and *d* 4 in the upper jaw, and to *d* 3 and *d* 4 in the lower jaw.

The first is implanted by two fangs, the second by three, the third by four fangs; the shape of these teeth is sufficiently illustrated by the figures.

Their rate of increase in size from the first to the last is considerable, yet not equal to that manifested in the true molars. Upon examining the substance of the jaws above the deciduous molars of the upper jaw and beneath those of the lower jaw, two formative alveoli and the trace of a third were detected in the upper jaw, one above *d* 4, containing the crown of a premolar; the other above *d* 3, and the rudimental cell above *d* 2. The matrix, which the latter might have contained, had not begun to be calcified. A small formative socket was found beneath the last milk-molar of the lower jaw containing the crown of a premolar. The gubernacular canal from this socket opened between the fangs on the inner side of the milk-tooth. A second still smaller socket of an anterior premolar was beneath the interspace between the two milk-molars.

The true nature of the molar behind the milk-teeth in both jaws was plainly shown by its long fangs extending beyond the parallel of the formative sockets of the successors of the milk-teeth, and widely open at their ends: this tooth has no vertical successor and is the first true molar, *m* 1. Only the crown of the second true molar (*m* 2) is formed at the stage here described; and a few detached columns of the still larger and more complex third molar (*m* 3) were all that were calcified in its commencing formative alveolus.

In none of the other members of the Hog family is the first true molar ($m\ 1$) so much worn down at the corresponding early stage of development of the second true molar, and it is upon this precocious growth of the first true molar that the chief peculiarity of the order of shedding of the teeth of the *Phacochæri* depends.

In the *Phac. Æliani*, the penultimate and last milk-teeth ($d\ 3$, $d\ 4$) in the upper jaw are displaced and succeeded by corresponding premolars, which therefore answer to $p\ 3$ and $p\ 4$ of the typical series. The anterior small milk-grinder, $d\ 2$, is sometimes succeeded by a minute premolar, but occasionally this is abortive, or absorbed before it cuts the gum. In the lower jaw both milk-molars ($d\ 3$ and $d\ 4$) are succeeded by the corresponding premolars $p\ 3$, $p\ 4$, at least in the *Phac. Æliani*.

The stage of dentition of the *Phac. Æliani*, given in figs. 1, 2 and 3, corresponds with that in the common Hog, illustrated by the teeth in the lower jaw in Plate XX. fig. 1 of the Philosophical Transactions for 1801. In that figure the last grinder in place is the first true molar, $m\ 1$; the penultimate is the last milk-molar, $d\ 4$; the next is $d\ 3$, the next $d\ 2$; and a little in advance of this, between it and the rudimental canine, is the small anterior premolar, $p\ 1$. The germs of the other premolars, $p\ 2$, $p\ 3$ and $p\ 4$, are shown in their formative sockets beneath the deciduous teeth they are destined to replace.

If the symbols above given be marked upon the teeth in the figure cited, the homologies of those in the reduced dentition of the young Wart-Hog will be readily appreciated. The teeth developed in the lower jaw of that species are,— $d\ 3$, $d\ 4$, $p\ 3$, $p\ 4$ and $m\ 1$: in both jaws $m\ 2$ has only its crown developed, and $m\ 3$ only the commencement of its crown. The teeth which are suppressed in the *Phac. Æliani* are, in the lower jaw, $d\ 1$, $d\ 2$, $p\ 1$ and $p\ 2$. In the upper jaw $d\ 1$ and $p\ 1$ are suppressed, and sometimes also $p\ 2$.

The next stage of dentition (Plate XXXIV. figs. 4 and 5) shows the shedding of the deciduous molars to be concomitant with the coming into place of the second true molar, $m\ 2$; it is well illustrated in the cranium of a young *Phac. Æliani* from Senegal in the Museum of Comparative Anatomy in the Garden of Plants: in which each of the three deciduous molars of the upper jaw have been succeeded by a premolar ($p\ 2$, $p\ 3$, $p\ 4$, fig. 4), and the same with regard to the two deciduous molars in the lower jaw ($p\ 3$, $p\ 4$, fig. 5). The anterior angle of the crown of the last huge molar has also begun to protrude from the formative alveolus, so that the permanent or second molar series now shows $\frac{6-6}{5-5}=22$, which is the greatest number of grinders presented at any given time in the genus *Phacochærus*. The first true molar, $m\ 1$, is however worn to near the fangs, and its grinding surface, as compared with that in Plate XXXIII. fig. 2, begins to be simplified. The homologies of the teeth at this period are indicated by the symbols attached to them in the figures.

The stage of dentition of the young *Phac. Pallasii*, figured by HOME in tab. xix. of his memoir, is a little more advanced than that of the *Phac. Pallasii* above de-

scribed; but although scarcely half the grinding surface of the last molar, *m* 3, has come into use, all the premolars in advance of the last, *p* 4, have been shed, Plate XXXIV. fig. 8.

In the specimen of *Phac. Æliani*, of which the grinding surface of the teeth is figured in Plate XXXIV. figs. 6 and 7 of the present memoir, although the major part of the last large grinder is in use, the penultimate premolar (*p* 3) is retained as well as the last (*p* 4). The molar series here shows 5—5 in the upper jaw and 4—4 in the lower jaw; their homologies are indicated by the symbols attached. By reason of the precocious development of *m* 1, we now find it quite worn down to the fangs; and in the lower jaw (fig. 7) it is wedged between *p* 4 and *m* 2 into a space which is two-thirds less than the antero-posterior extent of the crown of the same tooth shown in the younger specimen (Plate XXXIII. fig. 2). The reduction of size of *m* 1 is however quite intelligible by observing the much-constricted neck from which the long fangs are continued in that specimen (see *m* 1, fig. 1).

The figures of the grinding surface (figs. 6 and 7) suffice for the characteristic forms of the grinding-teeth now in use.

The specimen of *Phac. Æliani* (No. 773. Mus. Coll. Chir.) shows the last remnant of *m* 1 wedged into the diminished interspace between *p* 4 and *m* 2, and the corresponding interspace in the lower jaw, from which such remnant of the first true molar has been shed.

The skull of an older *Phac. Æliani* (No. 772) shows the displacement of the first true molar in both jaws and the reduction of the molar series to $\frac{4-4}{3-3}$; the teeth being *p* 3, *p* 4, *m* 2 and *m* 3 above (fig. 9), *p* 4, *m* 2 and *m* 3 below (fig. 10). There is no vacuity now in the series to show a true molar to have been shed, as it has been in so unusual an order.

The next stage of dentition which I have observed in this species is the loss of the anterior premolar *p* 3, and the great wearing down of *m* 2 (fig. 11), and in one instance in the lower jaw *m* 2 was shed before *p* 3.

The skull of a male *Phacochærus* in the British Museum*, from the Cape de Verd, measuring 16 inches 6 lines in length, with the incisors of the *Phac. Æliani*, viz. $\frac{1-1}{3-3}$, and the same broad and shallow posterior channel upon the canines $\frac{1-1}{1-1}$, shows the same numerical molar formula as No. 772, but the teeth are different in the upper jaw, they are *p* 3, *p* 4, *m* 2 and *m* 3; in the lower jaw they are *p* 3, *p* 4 and *m* 3; both first and second true molars being shed in this jaw, whilst the last two premolars are retained.

In the skull of a female *Phacochærus*, $13\frac{1}{2}$ inches in length, from South Africa, in the British Museum, but with the incisive formula of the *Phac. Æliani*, the molar

* The term *Phacochærus Æthiopicus* is retained for the species represented by this skull in the British Museum.

series is $p \frac{1}{1}$, $m \frac{2-2}{2-2}$; the teeth in both jaws being $p 4$, $m 2$ and $m 3$: here the penultimate premolar has been shed before the penultimate true molar, the socket of which however alone indicates it in the lower jaw.

In a still older specimen, $p 3$ and $m 2$ have been shed in both jaws, and the dental series is reduced to $\frac{2-2}{2-2}$; the teeth being $p 4$, $m 3$ on each side of both jaws (fig. 12).

Finally, $p 4$ is shed, and only the great posterior molar remains, as in the old *Phac. Æliani* figured in tab. xviii. of HOME's memoir.

It is interesting and suggestive thus to observe that an analogous duration or longevity, so to speak, characterizes the last tooth of both premolar and true molar series; an analogy so little to be expected from their different size and widely different original position in the jaws, by which characters, HOME, not sufficiently extending his observations and trusting to the analogy of the Elephant, was misled.

With respect to the *Phac. Pallasii*, my opportunities of tracing the course of dentition are not so extensive as with regard to the *Phac. Æliani*. I have observed none younger than the specimen figured by HOME (tab. xix.), and am not acquainted, therefore, with the characters of its deciduous dentition.

All the four teeth on each side of the upper jaw of that specimen, and there are the same number in the lower jaw, belong to the permanent series; tracing them from before backwards they are $p 4$, $m 1$, $m 2$ and $m 3$ in both jaws. The homologue of $p 3$ in the upper jaw of *Phac. Æliani*, if it be developed, is sooner shed in the *Phac. Pallasii* than in the *Phac. Æliani*. From the defects that have been pointed out in HOME's reduced figures of these teeth, more accurate views of them of the natural size may be acceptable, especially as they have not been elsewhere represented. I subjoin, therefore (Plate XXXIV. fig. 8), a side view and a view of the grinding surface of each. These figures, also, preclude the necessity of verbal description. I will only state that $p 4$, in the upper jaw, is implanted by three fangs, and is relatively smaller than its homologue in *Phac. Æliani*: $p 4$ in the lower jaw offers corresponding differences with its homologue in *Phac. Æliani*; $m 2$ has a narrower crown in relation to its antero-posterior extent than in *Phac. Æliani*; and a similar and more compressed form distinguishes the third molars in both jaws of the *Phac. Pallasii*. In the skull of a female Phacocoerus, called 'Haruja,' from Caffraria, in the British Museum, which differs from the typical *Phac. Æliani* of North Africa in having only two incisors in each ramus of the lower jaw, the following is the dental formula:—

$$i \frac{1-1}{2-2}, c \frac{1-1}{1-1}, p \frac{2-2}{1-1}, m \frac{2-2}{2-2}:$$

the grinders of the upper jaw are $p 3$, $p 4$, $m 2$ and $m 3$: those of the lower jaw are $p 4$, $m 2$ and $m 3$. The first true molar has been shed, and its place obliterated in both jaws.

There is a stuffed skin of this species which shows the same number of incisors, viz. $\frac{1-1}{2-2}$.

I have seen no stage of dentition of the *Phac. Pallasii* corresponding with figs. 6 and 7 of *Phac. Æliani*. The next example, after the stage figured by HOME, is shown in a skull from the Guinea Coast, in which the grinding series includes 3—3 in both jaws, like that in the upper jaw of the *Phac. Pallasii* and lower jaw of the *Phac. Æliani*, figured in 'Les Dents des Mammifères' of M. F. CUVIER, Tab. 87. These teeth, in each case, are *p* 4, *m* 2 and *m* 3 on each side of both jaws. In the specimen before me, *p* 4 is much worn, and is pressed into close contact with *m* 2. The anterior half of the grinding surface of this tooth is worn down to the common dentinal base, and both the anterior and posterior surfaces of the crown are excavated by the pressure of the two contiguous teeth, as in fig. 10. That a large grinder, like *m* 1, figs. 4, 5 and 6, should have been interposed between the first and second grinders in the specimen here described, could never have been suspected without a knowledge of those earlier stages of the dentition of the genus which have been described.

Baron CUVIER describes the molar teeth of the Phacochere as being three on each side of both jaws in the 4to edition of the 'Ossements Fossiles' (1822)*, and the same numerical formula is retained in the posthumous 8vo edition of 1834†. With regard to the mode of succession of these teeth, the Baron adopts the conclusions of Sir EVERARD HOME; and in both editions of the 'Règne Animal,' after noticing the similarity of composition of these teeth with the grinders of the Elephant, he adds that they, in like manner, succeed one another from behind forwards‡.

His brother, M. FR. CUVIER, adopting the same view in the 'Dents de Mammifères,' describes the dentition of the Wart-Hogs as differing altogether from that of the rest of the Hog-tribe. "Nous voici arrivés," he writes, "à un système de dentition tout à fait différent de celui des sangliers" (p. 213): he adopts the specimens represented in the pl. 87 above cited, and describes the figures of that plate as exemplifying the normal adult dentition of the genus§. The anterior of the three grinders is described as the 'première mâchelière' (p. 214); and the second as 'la seconde mâchelière,' the latter being said to be composed of four tubercles, which by usage present four little elliptical or circular figures surrounded by enamel. And this, indeed, is the case at the extreme stage of attrition which he has figured; but, at an earlier period of usage, the crown of the tooth presents ten of those enamel-girted circular or elliptical islands of dentine, surrounding two, three, or four median ones (figs. 4, 5, 6, *m* 2). The last large molar presents twenty-five of these islands in the upper jaw in three linear series, nine being central, and twenty-six in the lower jaw, nine

* Tom. ii. p. 123.

† Tom. iii. p. 235.

‡ Tom. i. p. 244.

§ In this he is followed by LESSON (Manuel de Mammalogie, p. 340), FISCHER (Synopsis Mammalium, p. 423) and other systematic mammalogists, who assign molars $\frac{3-3}{3-3}$ as one of the characters of the genus *Phacochærus*.

also being central, and the islands smaller and more regularly disposed. This tooth extends to within one or two lines of the thin compact inferior bony wall of the deep ramus of the jaw, where the constituent columns terminate in the basal openings of as many pulp-cavities, with the exception of the first four, which are blended together, and from which no root has begun to be developed. It is therefore plain that this large and singularly complex grinder will continue to serve the purposes of mastication long after the shedding of the molar in advance, and the substance of which is already wasting away by the pressure of the larger tooth. We shall see, in the next specimen, that that molar is actually worn away and shed, whilst the smaller grinder in advance of it remains.

In the lower jaw of the specimen (No. 775 A.), the gum has grown over the sockets of the second true molar between the persistent remnant of the fourth premolar and the third true molar. In the upper jaw the last remnant of the second true molar remains on the right side, the crown having been worn to its base and the fangs absorbed.

Thus, in the *Phac. Pallasii*, as in the *Phac. Æliani*, the last of the premolar series, like the last of the true molar series, is distinguished by its longevity, although inferior in this respect to the large true grinder which continues to do the work of mastication to the end of the animal's existence.

The analogy of the Phacochæres to the Elephants in the superior size, complexity, and duration of the last grinders is close and interesting; but it does not extend to the horizontal mode of succession, in other words to the absence of premolars or vertical successors of deciduous teeth, as HOME led CUVIER to believe. In the development and succession of these premolars, and in the shape, proportions and position of the true deciduous teeth, the Wart-Hogs much more closely and essentially agree with the rest of the *Suidæ*. They differ, however, as we have seen, in the inferior number of both milk-molars and premolars which are developed, and in the speedier loss of all the true molars in advance of the last large one; but, in the order of shedding of those teeth, more especially in the very early displacement of the first true molar, and the total obliteration of its place in the series by the approximation of the last premolar to the second true molar, and in the subsequent displacement of this tooth with the approximation of the last premolar to the last true molar, the genus *Phacochærus* is quite peculiar and different from all other Mammalia.

The author, who first called the attention of naturalists to the peculiarities of the dentition of the *Phacochæri*, has indicated another difference between the Wart-Hog and the common Hog, by affirming that the latter has a molar tooth developed behind the third true molar, at least in the lower jaw; which, if it were so, would have shown the common Hog to differ, also, from almost every other placental mammal with two sets of teeth*. In the description of Plate XX. of the Philoso-

* The *Megalotis Lalandii* is the only example, as far as I have observed, of the constant occurrence of *four* true molars on each side the lower jaw: the typical number *three* being retained above.

phical Transactions for 1801, HOME states that "fig. 3 represents the jaw in a still more advanced stage of its growth, with the tooth which was only forming in the second figure now come to its full size, and in its proper place in the row of teeth: there is also a new cell formed for a succeeding tooth*." The original specimen from which the figure is taken is preserved in the Hunterian Collection, and it shows that the supposed formative cell is one of a series of the medullary cells of the cancellous structure of this part of the jaw; it is itself subdivided into smaller cells, and is not a simple cavity like the true cell of a forming tooth. It is also represented of twice its natural size in the figure cited, not having been reduced in proportion to the other parts of the jaw.

The latest author on the subject of the dentition of the *Phacochæri*, has ascribed to that part of their structure a character which would have added a still more remarkable anomaly to it, viz. that the last true molar represents both that tooth and the penultimate one in the Wild Boar and other herbivorous mammals†.

To this conclusion M. DE BLAINVILLE was necessarily led by his determination of the antecedent teeth. Thus in a *Phacochærus* with the dentition answering to that represented in figs. 4 and 5 of the present memoir, he regards the teeth marked *p* 3, *p* 4 and *m* 1 as belonging to the deciduous series, 'dents de lait‡,' and the rest as belonging to the second dentition; *p* 2 being described as a small, speedily lost, false molar, *m* 2 as the first or antepenultimate true molar, and *m* 3 as the penultimate and last true molars, "already blended together, although not yet protruded from their formative alveolus§."

With regard to the five teeth in the lower jaw, the first, *p* 3, is described as the first tooth of the second dentition; the two following, *p* 4 and *m* 1, as milk teeth; the fourth, *m* 2, as the antepenultimate molar of the second dentition, and the last, *m* 3, as the penultimate and last molar coalesced. The dentition ascribed to the adult *Phacochærus* is that phase which is illustrated in figs. 9 and 10, Plate XXXIV. of the present memoir, of which the numerical formula is $\frac{4-4}{3-3} = 14$. M. DE BLAINVILLE, struck by the resemblance in the degree of attrition which the molar, *m* 2, presents to the antepenultimate molar, *m* 1, in the adult common Hog, deems them homologous, and deduces from that resemblance another argument for the homology of the last great molar of the Phacochære with the penultimate and last molars combined of the Hog||.

* Philosophical Transactions, 1801, p. 331.

† Ostéographie des Ongulogrades, *Hippopotamus* and *Sus*, 4to, 1847. ‡ Ibid. p. 148. § Ibid. p. 148.

|| "Mais quelle est la signification de cette dent par rapport à ce qui existe chez la sanglier? C'est la une question qui, malgré son intérêt, n'a pas même encore été soulevée.

"J'ai cru un moment qu'on pourrait la considérer comme représentant les trois arrière-molaires qui se seraient soudées de manière à n'en former qu'une, les trois molaires qui la précèdent étant alors celles de remplacement. Cette façon de voir était surtout appuyée sur la composition de cette dent à la mandibule où l'on peut voir dans les cannelures latérales des séparations plus marquées, paraissant indiquer l'antépénultième, la pénultième et la dernière avec son talon.

"Mais en réfléchissant sur le caractère sérial des espèces de ce genre, il m'a semblé que cette opinion devait
MDCCCL.

But had the preceding stage of dentition, which is represented in fig. 7, Plate XXXIV., presented itself to the observation of M. DE BLAINVILLE, that acute observer would doubtless have seen that *m* 1,—the true homologue of the much-worn antepenultimate molar of the common Hog,—presented the same abraded condition. And the actual difference is as follows, viz. that, owing to its earlier development in the *Phacochærus*, the true antepenultimate molar, *m* 1, is sooner worn out and shed; whilst, from the very long period during which the last molar is adapted to perform the work of mastication, the penultimate molar, *m* 2, undergoes the same exhaustive usage and premature expulsion.

I have figured in parallel juxtaposition the molar series of a Phacochere and a Wild Boar, in plate 141 of my 'Odontography,' to illustrate the corresponding extent of abrasion in the first or antepenultimate true molar (*m* 1) at the period when the last true molar has come into place in the Wart-Hog, and when two of the premolar series are retained; and I have indicated my conclusions as to the signification or homology of each of the teeth by the symbols, the aptness and exactitude of which all my later researches have convinced me of. With regard to the deciduous teeth of the Phacochere and other diphyodont mammals, I may remark that there is but one mode of determining and of distinguishing them from the premolars and true molars of the second dentition, in cases where some of the latter are obviously present, as in the young Phacochere with a grinding series of $\frac{6-6}{5-5}$ (see figs. 4 and 5) or of $\frac{5-5}{4-4}$ (as in Plate XXXIII.): that mode is to excavate the substance of the jaws above the fangs of the upper teeth and beneath those of the lower ones, as in the skull represented in Plate XXXIII., and in the lower jaw figured in my 'Odontography,' pl. 141, fig. 1*. The deciduous tooth is demonstrated by the formative

être modifiée, et que dans cette dent il ne fallait voir que les deux dernières, et alors la terminale aurait son talon dans la proportion convenable.

"Ce qui milite encore en faveur de cette manière de voir, c'est que la dent sur laquelle porte davantage l'usure dans le sanglier, l'antépénultième ou cinquième, a son analogue chez le sanglier d'Ethiopie dans la dent qui précède la dent complexe, et qui serait en effet l'antépénultième, celle-ci représentant la pénultième soudée à la dernière.—*Loc. cit.* p. 148.

* "Le système dentaire de cet animal a été fort incomplètement figuré sans description par EVERARD HOME (Lect. on Comp. Anatom. t. 11. pl. 38 et 39), M. G. CUVIER lui a consacré un court paragraphe (Ossem. Foss. t. 11. p. 132, sans figures), et M. OWEN s'est borné à représenter la couronne des molaires supérieures du côté droit (Odontographie, pl. 140, fig. 31), mais personne n'en a soupçonné la signification." M. DE BLAINVILLE had overlooked pl. 141, where that signification is given: but he adds in a supplementary note,—"Il relève, comme inexacte, l'assertion de M. RUPPELL, que dans tous les individus des deux sexes, jeunes et adultes, il y a quatre molaires en haut et trois en bas; et en effet il en décrit une de plus, en reconnaissant que dans la première dentition il n'y en a que trois à la mâchoire et deux à la mandibule. Du reste M. R. OWEN accepte la distinction spécifique du *S. Eliani* et du *S. Pallasii*; le premier pourvu et le second dépourvu de dents incisives, mais sans autres différences vraiment spécifiques." If, however, the difference cited be of specific value, as M. DE BLAINVILLE seems here to admit, others were not needed for accepting the conclusion. I may, however, add that the upper canines of the *Phac. Pallasii* have the groove on their upper surface narrower than in the *Phac. Eliani*, and that the premolars are relatively smaller.

socket containing the germ of its successor in a vertical line with it; this is more especially the case with the last or hindmost deciduous tooth, because the hindmost premolar, its successor, is late in coming into place, and the contiguous true molar, which is always formed much sooner, is characterized by its deeply implanted fangs, and by the absence of any formative socket in vertical relation to them. Without the dissection of the jaws figured in Plate XXXIII., I could have had no true or scientific knowledge of the nature of the teeth there symbolized. As I availed myself of symbols to denote the signification or homology of the teeth of the *Phacochærus* in my 'Odontography' (pages 549 to 557, pl. 140, 141), I shall sum up or indicate in the same way the results of the additional observations recorded in the foregoing pages.

Phases of the molar series of the genus Phacochærus.

Phase

- I. Plate XXXIII. $\frac{5-5}{4-4}$ viz. $\begin{cases} d2, d3, d4, m1, m2. \\ d3, d4, m1, m2. \end{cases}$
- II. Plate XXXIV. figs. 4 and 5, $\frac{6-6}{5-5}$ viz. $\begin{cases} p2, p3, p4, m1, m2, m3. \\ p3, p4, m1, m2, m3. \end{cases}$
- III. Plate XXXIV. figs. 6 and 7, $\frac{5-5}{4-4}$ viz. $\begin{cases} p3, p4, m1, m2, m3. \\ p4, m1, m2, m3. \end{cases}$
- IV. Plate XXXIV. fig. 13 (*Phac. Pallasii*), $\frac{4-4}{4-4}$ viz. $p4, m1, m2, m3.$
- V. Plate XXXIV. figs. 9 and 10, $\frac{4-4}{3-3}$ viz. $\begin{cases} p3, p4, m2, m3 \\ p4, m2, m3 \end{cases}$ (or $\begin{cases} p3, p4, m2, m3. \\ p3, p4, m3. \end{cases}$)
- VI. Plate XXXIV. fig. 11, $\frac{3-3}{3-3}$ viz. $p4, m2, m3.$
- VII. Plate XXXIV. fig. 12, $\frac{2-2}{2-2}$ viz. $p4, m3.$
- VIII. $\frac{1-1}{1-1}$ viz. $m3.$

The above symbols express, with regard to the first phase, *I. e. g.*, that there are five grinders on each side of the upper jaw, and four grinders on each side of the under jaw: that those above answer to the second, third, and fourth deciduous molars, and to the first and second permanent true molars; and that those below answer to the third and fourth deciduous molars, and to the first and second true molars,—of the typical dentition. With regard to the second phase, the symbols express that there are six grinders on each side of the upper, and five grinders on each side of the under jaw: those above answering to the second, third and fourth premolars, and to the first, second and third true molars; those below answering to the third and fourth premolars, and the first, second and third true molars—of the typical dentition.

As to the fourth phase with four grinders on each side of both jaws, these answer,

in both, to the fourth premolar, and to the first, second and third true molars of the typical dentition of the placental Diphyodonts.

These explanations will serve to render the symbols of the remaining phases readily understood by those who may not have studied the principles of dental notation which I communicated to the 'British Association' in 1848, and have more fully exemplified in the article 'Teeth' of the 'Cyclopædia of Anatomy and Physiology'; their utility will be obvious when they are found to express, in a few lines, facts in Comparative Anatomy which would require almost as many pages if recounted by ordinary description.

This system of anatomical notation is the practical fruit of the discovery or determination of a type or common pattern of dentition to which the teeth of a certain proportion of the Animal Kingdom could be referred, and of a concomitant attainment of the power to trace a particular tooth under every modification and disguise of size and shape, throughout the different species of those animals. Every tooth, thus capable of being individualized and determined, merits and, for the purposes of description, requires to have a proper name, and can be signified by a symbol, which is still more convenient for those purposes.

The dental system manifests this regular and determinable character in a large proportion of the mammalian Class; but not in any animal of inferior organization. Like the definition of a species, the definition of a tooth or other part of an organism becomes possible only when its characters are constant and definite, and is easy in proportion as those qualities are exalted. The definition of a mineral species is more difficult than that of a vegetable species, and the definition of a species of low cellular plant is more difficult than that of the highly organized dicotyledon. In proportion as wholes rise in the scale of nature or of life, their recognition and definition becomes easier, and the like obtains also of their parts. As animals ascend in the scale of complexity their organs and parts become more definite; and homologies are more extensively, easily and satisfactorily determinable.

We cannot point out in one species of *Echinus* the answerable spine of any given spine in another species, nor can we determine the homology of a tufted foot from one species of the many-jointed Annelides to another; but in insects each particular leg may be determined through all its modifications of form and function throughout the class. So, likewise, with the teeth: the same individual tooth cannot be traced from fish to fish, or from reptile to reptile; the teeth in the cold-blooded classes differ too much in their number in different individuals, and too little in their development and succession, to yield the requisite characters to the homologist who keeps his faculty of comparison under due control. In those Mammalia, likewise, as *e. g.* the Cachalots, Dolphins and Armadillos, in which the teeth are very variable in number and often very numerous, but without any definite order of shedding and replacement, no particular tooth can be identified and traced from one species to another.

The class *Mammalia* presents, in fact, two primary conditions of the dental system, according to which it might be divided into,—

- 1st. Those that generate one set of teeth, or the 'Monophyodonts*,' and
- 2nd. Those that generate two sets, or 'Diphyodonts†.'

The 'Monophyodonts' include the orders *Monotremata* and *Bruta* (or the *Edentata* of CUVIER) and the *Cetacea vera* of CUVIER.

The Diphyodonts include the *Marsupialia*, *Rodentia*, *Insectivora*, *Cheiroptera*, *Ruminantia*, *Pachydermata*, *Sirenia*, *Carnivora*, *Quadrumana* and *Bimana*.

I would not be misunderstood, however, as proposing this difference as a basis of classification: such dental characters are associated with too few corresponding differences of organization to lead to a natural binary division of the *Mammalia*. But, as regards the philosophy of the organs in question, considered in that class, the differences above enunciated form one of the highest generalizations, and the exigencies of clear and brief description require such general ideas to have their appropriate signs or names.

The Diphyodont Mammals, then, are characterized by having a first set of teeth, commonly called the 'milk-teeth' or 'deciduous teeth,' and a second set called the 'permanent teeth.' But the development of the latter, in relation to the milk-teeth, presents two modifications; some of the permanent teeth are found in the same vertical line with the milk-teeth, push them out and take their place; others are formed one after another behind the milk-teeth, in what may be called the same horizontal line, and come into place without pushing out any deciduous predecessors. Here, therefore, we have certain characters from development for particular teeth, and when to these characters are added others of equal constancy, derived from relative position, it will be readily understood how such characters, when clearly appreciable and firmly maintained through a series of comparisons, should enable the homologist to point out the very tooth in Man which becomes the great carnassial tooth in the jaw of the Tiger or the great complex grinder in that of the Wart-Hog. With respect to the accessory characters, one of the best is afforded by the relation of certain teeth to the constituent dentigerous bones of the complex jaws. Implantation in the premaxillary bone, or premaxillary part of the upper jaw, *e. g.*, characterizes the tooth called 'incisor,' whatever be its shape or size; and the true and constant character of such tooth being thus determined, the name 'incisor' becomes its arbitrary sign and loses all its primitive signification as descriptive of a particular shape or use. In like manner the tooth at the fore part of the maxilla, or the maxillary part of the upper jaw which coalesces with the premaxilla in Man, is called the 'canine.' The molar series, according to the characters of development and succession above described, is divided into 'milk-molars,' 'premolars' and 'true molars.' The two latter kinds constitute the adult or permanent set of molars. Now these, in the diphyodont mammals, do not exceed $\frac{7-7}{7-7}=28$, *i. e.* seven on each side of both jaws. In the marsupial Diphy-

* Μόνος once; φύω I generate; ὀδούς, tooth.

† Δίς twice; φύω and ὀδούς.

odonts three of the seven on each side of both jaws are 'premolars,' four are 'true molars.' In the placental Diphyodonts four of the seven on each side of both jaws are 'premolars,' and three are 'true molars.' The exceptions, by way of excess to this typical number, are few and are confined to the marsupial order, *e. g.* in the *Myrmecobius*: the deviations from the type by deficiency are numerous, especially in the placental series. But to whatever point the number may be reduced, the teeth that are retained may be identified with their homologues in the typical series. This power is fortunately given by the constancy in respect of their existence of the contiguous teeth of the premolar and molar series, those, *e. g.* marked *p* 4 and *m* 1 in Plate XXXIII.; and by the absent teeth being taken from a definite part of each of those series, viz. from the fore part of the premolars and from the back part of the true molar series.

The Bears and some Carnivora offer a partial exception in the occasional retention of *p* 1 when *p* 2 and *p* 3 may be absent, but *p* 4 is constantly present.

Thus it needs only to determine, in any given species of diphyodont mammal, the last premolar and the first true molar, as has been done in the young *Phacochere*, Plate XXXIII., in order to know the homologies of the rest. The true molars are counted from before backwards,—'first,' 'second,' 'third:' the premolars from behind forwards,—'fourth,' 'third,' 'second,' 'first,' or as far as the series may extend. In Man, *e. g.* it stops at the third; the first and second, which exist in the Hog, being absent, but all the true molars are present. The teeth being thus determined their symbols can be applied to them, *m* 1, *m* 2, *m* 3, for the molars,—*p* 4, *p* 3, *p* 2, *p* 1, for the premolars. It needs only to apply the symbols to one side of each jaw, the teeth being symmetrically repeated on the opposite side: and in most cases they are alike in both jaws. The right canine is the homotype of the left canine, as the right arm is of the left arm, agreeably with the principle of 'bilateral symmetry:' the first true molar in the lower jaw is the homotype of the first true molar of the upper jaw, as the leg is the homotype of the arm, in accordance with the law of the composition of the vertebrate framework of a successive series of essentially similar segments. In whatever direction or to whatever degree two or more of these segments may deviate from the type, the same elements may be discerned in them beneath those modifications. If the neural arch be vastly expanded, as in the cranial vertebræ of mammals, we trace the broad and bifid neural spine from one to the other, and recognise, *e. g.* the frontal bones and parietal bones as homotypal elements. If the diverging appendages be the seat of adaptive development, as in the occipital and pelvic vertebræ, we find the same plan of modification is followed, and we can trace the homotypal parts, *e. g.* *humerus* and *femur*, *radius* and *tibia*, *ulna* and *fibula*, *carpus* and *tarsus*, as also the homotypal ossicles in the carpus and tarsus, even when the common plan is so varied in such appendages, as to produce the different powers and functions which characterize the leg and the arm in Man.

So, likewise, when two costal arches are converted into jaws and made to support teeth, we find the same laws of development so strictly followed as to enable us to

determine the homotypal teeth in those two jaws with the same certainty as the homologous teeth in the jaws of different species.

When the mouth is shut the teeth in the lower jaw are a little in advance of their homotypes in the upper jaw; thus in the Carnivora the great canine tooth of the lower jaw always passes in front of the canine above. Even in the human subject this characteristic relative position is shown by the molars and premolars, when the upper incisors are produced beyond the lower ones.

The existing species of Mammalia that retain the typical formula of dentition, viz.

$$i \frac{3-3}{3-3}, c \frac{1-1}{1-1}, p \frac{4-4}{4-4}, m \frac{3-3}{3-3} = 44,$$

are few: but that formula was much less frequently departed from in the species of placental Mammalia which were first introduced into this planet. This is a very significant fact, and became manifest in the course of working out such typical formula by tracing and comparing the development of the teeth in the recent species.

In the oldest known strictly carnivorous mammal, *e. g.* the *Hyænodon*, remains of which have been discovered in the newer eocene deposits of Hampshire, and in the miocene formations of France, the complete typical dentition is retained, and each of the three true molars presents the peculiar trenchant form of crown which characterizes the single tooth called by CUVIER 'le dent carnassière' in the Lion: here, therefore, we use the term 'molar' in the same technical or arbitrary sense as the term 'incisor' when applied to the tusks of the Elephant or the prongs of the Hippopotamus. In the mixed-feeding *Amphicyon*, a larger extinct miocene Carnivore allied to the Plantigrades, the three true molars have broad tuberculate crowns. Almost all the herbivorous genera of the eocene and miocene tertiary periods had the typical number and kinds of teeth, as, *e. g.*, *Anoplotherium*, *Palæotherium*, *Dichodon*, *Chæropotamus*, *Dichobune*, *Anthracotherium*, *Hyopotamus*, *Hyracotherium*, *Oplotherium*, *Merycopotamus*, *Hippohyus*, &c. When a modern genus or family has been represented as far back as the miocene period by extinct species, it is usual to find some nearer approach made by such species to the typical dentition than is made by the existing species. Thus, in existing Ruminants, the first premolar is suppressed; but in the ancient *Dorcatherium* it was retained. In the modern *Hippopotami* the incisors are reduced to $\frac{2-2}{2-2}$, and the first premolar is speedily lost; in the oldest known representatives of the genus—the *Hexaprotodon* of the Himalayan tertiary beds—the incisors were in the typical number $\frac{3-3}{3-3}$, as the name imposed upon it by its discoverers, CAUTLEY and FALCONER, indicates, and the first premolar was long retained; the whole dentition, in short, presented the typical formula.

The existing species of the gigantic Proboscidian family, viz. the Asiatic and African Elephants, are totally devoid of incisors in the lower jaw, and all their grinding-teeth succeed each other horizontally; so that it is only by a more than proportional in-

crease of size that the antepenultimate grinder is recognizable as the first of the true molar series, and the antecedent smaller grinders as the homologues of the milk-molars of other Diphyodonts, which milk-molars have no vertical successors in the Elephants. In certain Mastodons, however, which are the earliest known forms of the Proboscidian family, the last milk-molar was displaced by a vertical successor or premolar. Two incisors, moreover, were developed in the lower jaw of the young Mastodons, one of which was retained in the male of the *Mastodon giganteus* of North America, and both in that of the *Mastodon longirostris* of Europe.

The human dentition deviates from the typical formula by the suppressed development of several teeth; as might be anticipated from the characteristic shortness of the jaws, which is such as only to allow space for the comparatively few teeth retained, in close juxtaposition, without any break in the series.

The numerical formula is

$$i \frac{2-2}{2-2}, c \frac{1-1}{1-1}, p \frac{2-2}{2-2}, m \frac{3-3}{3-3} = 32;$$

the principal phases in the development of this dentition may be symbolized as follows:—

$$\text{I. 3 years old, } i \frac{2-2}{2-2}, c \frac{1-1}{1-1}, m \frac{2-2}{2-2} = 20;$$

all of the deciduous series, the molars answering to *d* 3 and *d* 4 of the typical dentition.

$$\text{II. 7 years old, } i \frac{2-2}{2-2}, c \frac{1-1}{1-1}, m \frac{3-3}{3-3} = 24;$$

the molars being *d* 3, *d* 4, *m* 1.

$$\text{III. 10 to 12 years old, } i \frac{2-2}{2-2}, c \frac{1-1}{1-1}, m \frac{3-3}{3-3} = 24;$$

the molars being *p* 3, *p* 4, *m* 1, and the milk incisors and canines replaced by the permanent ones.

$$\text{IV. 12 to 16 years old, } i \frac{2-2}{2-2}, c \frac{1-1}{1-1}, m \frac{4-4}{4-4} = 28, \text{ viz. } p 3, p 4, m 1, m 2.$$

$$\text{V. 18 to 30 years old, } i \frac{2-2}{2-2}, c \frac{1-1}{1-1}, m \frac{5-5}{5-5} = 32, \text{ viz. } p 3, p 4, m 1, m 2, m 3.$$

The teeth which are wanting in Man to complete the typical formula are *i* 3, *p* 1 and *p* 2. The teeth in Man which answer to the carnassials of the Lion and other Feræ are *p* 4 in the upper jaw, or the second bicuspid of human anatomy, and *m* 1 in the lower jaw, or the first multicuspid molar. The tooth which is homologous to the great complex molar of the Wart-Hog is *m* 3 in both jaws.

The symbols here proposed to denote the kinds of teeth are, it is hoped, so plain and simple as to present no obstacle to the ready comprehension of the facts which have been recorded by means of them. Had those facts been explained by means of the usual phrases or definitions of the teeth, *e. g.* "the second deciduous molar repre-

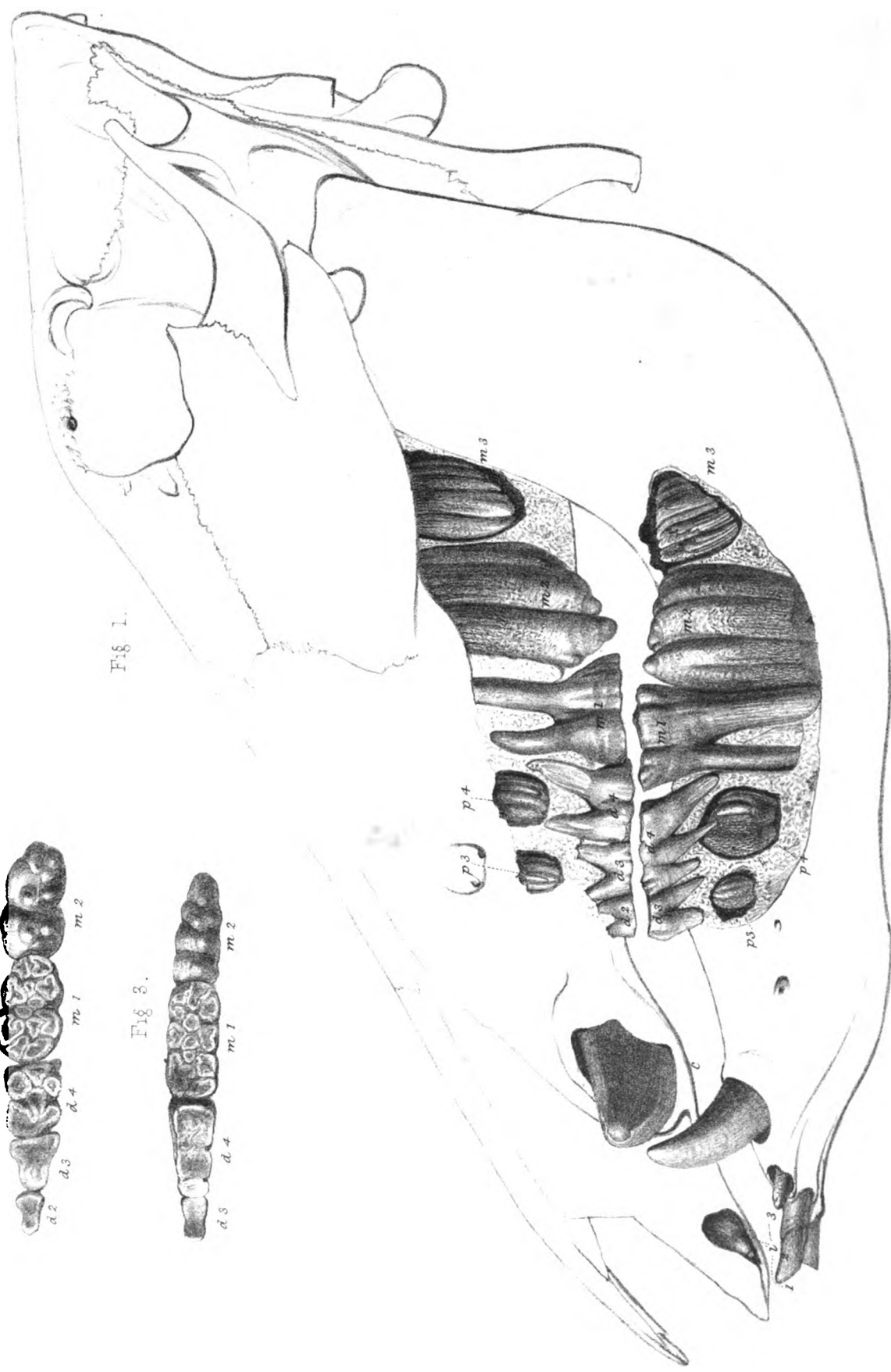
Fig 2.



Fig 3.



Fig 1.



W. D. D. del et sculp.

Young *Phacochærus Eliani*, Nat. Size

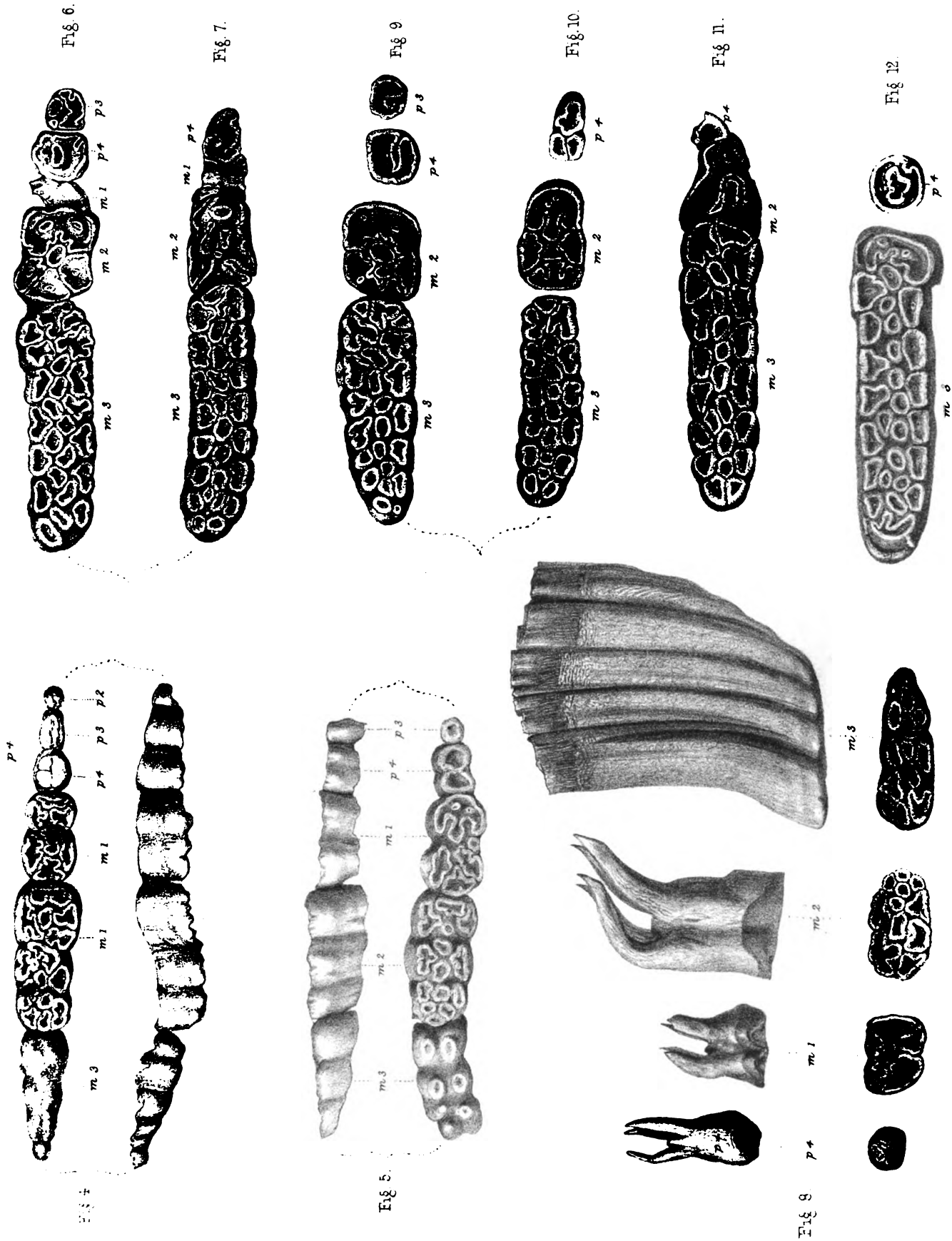


Fig.^s 1. 7. 9, 10 & 12. *Phacochærus Eliani*, Fig.^s 8 & 11 *Ph. Pallasii*.

via Drouot del. et lith.

senting the fourth of the typical dentition," instead of *d*4, and so on, the descriptions must have run to much greater length, and have levied such a tax upon the attention and memory as to have proportionally enfeebled the judgment and impaired the power of seizing and appreciating the results of the comparisons.

Each year's experience strengthens my conviction that the rapid and successful progress of anatomy depends greatly on the determination of the nature or homology of the parts observed, and on the concomitant acquisition of the power of denoting them by symbols equivalent to their single substantive names.

In my work on the 'Archetype of the Vertebrate Skeleton,' I have denoted most of the bones by simple numerals, which, if generally adopted, might take the place of names: and all the propositions, *e. g.* relative to the centrum of the occipital vertebra, might be predicated as effectually and intelligibly of the figure 1 as of the word 'basioccipital.' The symbols of the teeth are fewer, are easily understood and remembered, render unnecessary the endless repetition of the verbal definition of the parts, harmonize conflicting synonyms, serve as a universal language, and express the author's meaning in the fewest and clearest terms.

The Entomologist has long found the advantage of such signs as ♂ and ♀, signifying male and female, and the like; and it is time that the Anatomist should avail himself of this powerful instrument of thought, instruction and discovery, from which the Chemist, the Astronomer and the Geometrician have obtained such important results.

DESCRIPTION OF THE PLATES.

PLATE XXXIII.

Fig. 1. Side view of the skull of a very young *Phacochærus Æliani*, natural size, with the outer walls of the alveoli removed to expose the deciduous molars, premolars and true molars, *in situ*.

Fig. 2. The grinding series, composed of milk-molars and true molars, from the upper jaw.

Fig. 3. The same from the lower jaw. (The symbols are explained in the text.)

PLATE XXXIV.

Fig. 4. Grinding surface and side view of the crowns of the molar series of the upper jaw of a young *Phacochærus Æliani*.

Fig. 5. Grinding surface and side view of the crowns of the molar series of the lower jaw of the same skull.

Fig. 6. View of the grinding surface of the upper molar series of a full-grown but young *Phacchærus Æliani*.

Fig. 7. A similar view of the molar series of the lower jaw of the same specimen.

Fig. 8. Side view and view of the grinding surface of the molar series of a similarly aged *Phacchærus Pallasii*.

Fig. 9. View of the grinding surface of the upper molar series of an older *Phacchærus Æliani*.

Fig. 10. Similar view of the lower molar series of the same animal.

Fig. 11. View of the grinding surface of the upper molar series of an older *Phacchærus Pallasii*.

Fig. 12. Similar view of the upper molar series of a still older *Phacchærus Æliani*.
(The symbols are explained in the text, especially at p. 491.)

Fig. 12.



Fig. 15.



Fig. 13.



Fig. 16.

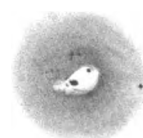


Fig. 14.



Fig. 17.

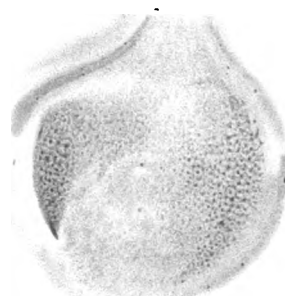


Fig. 9.



Fig. 6.



Fig. 7.



Fig. 10.



Fig. 8.

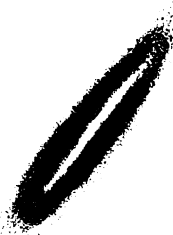


Fig. 11.



Fig. 3.



Fig. 4.

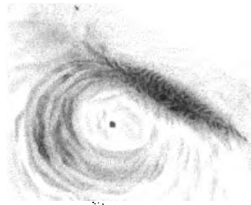


Fig. 5.



Fig. 1.

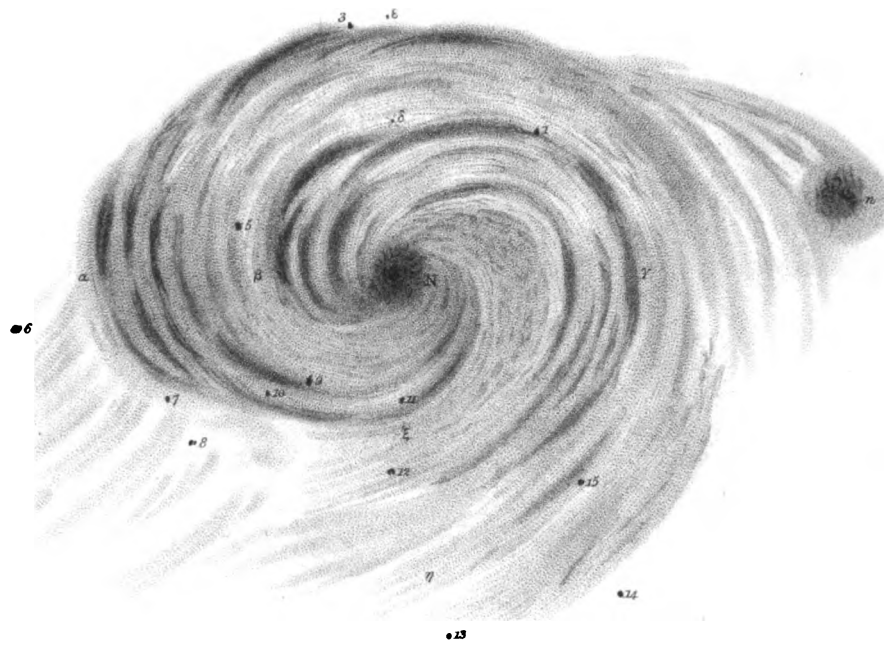
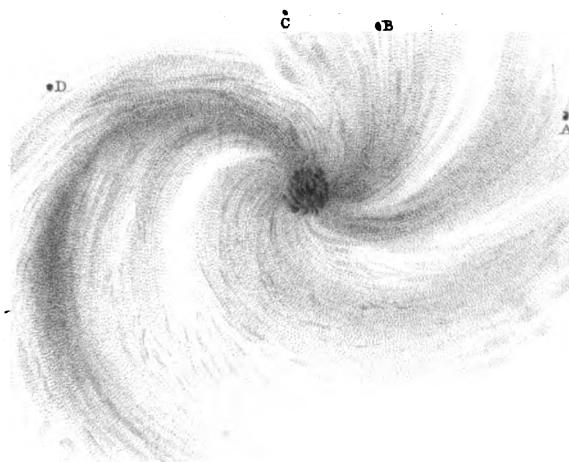


Fig. 2.



XXV. *Observations on the Nebulæ.* By The Earl of Rosse, Pres. R.S., &c. &c.

Received June 19,—Read June 20, 1850.

IN laying before the Royal Society an account of the progress which has been made up to the present date in the re-examination of Sir JOHN HERSCHEL'S Catalogue of Nebulæ published in the Philosophical Transactions for 1833, it will be necessary to say something of the qualities of the instrument employed.

The telescope has a clear aperture of 6 feet, and a focal length of 53 feet. It has hitherto been used as a Newtonian, but in constructing the galleries provision was made for the easy application of a little additional apparatus to change the height of the observer, so that the focal length of the speculum remaining the same, the instrument could be conveniently worked as a Herschelian.

Although with an aperture so great in proportion to the focal length, the performance of a parabolic speculum placed obliquely would no doubt be very unsatisfactory, still additional light is so important in bringing out faint details, that it is not improbable in the further examination of the objects of most promise with the full light of the speculum, *undiminished by a second reflexion*, some additional features of interest will come out.

The second reflexion is accomplished in the usual way by a surface of speculum metal; some experiments have been made, suggested by JAMIN'S paper in the *Annales de Chimie* for 1848, to procure a surface of silver suited to the purpose, but without complete success. Arrangements also have been for some time in contemplation with the view of effecting the second reflexion occasionally by a small glass prism; and about a year ago a prism was procured from Munich for the purpose: in both cases there would be a great saving of light; but I am speaking of the instrument as it is, not as it may become, if further improved.

The tube reposes at its lower end upon a very massive universal joint of cast iron, resting on a pier of stonework buried in the ground; and it is counterpoised so that it can be moved in polar distance with great facility. A quick motion in polar distance is given by a windlass below, and a slow motion is given by hand above for measurements. The extreme range of the tube in right ascension at the equator is one hour; but greater as the polar distance diminishes. The quick movement in right ascension is given below by a wheel turned by a workman, and the slow motion by hand above; the instrument is therefore completely under the dominion of the observer. The tube is slung entirely by chains, and is perfectly steady even in a gale of wind.

As the chain which governs the movement of the telescope passes over a pulley capable of being brought by a little subsidiary apparatus into a line drawn from the

axis of motion parallel to the axis of the earth, the movement of the telescope can be rendered almost exactly equatorial: there was some mechanical advantage in placing the pulley a little out of that line; and for such measurements as we have required, we have found the movement of the telescope sufficiently equatorial without the subsidiary apparatus, and therefore have not up to the present time made use of it. When the telescope is in the meridian, as it moves in polar distance it is guided by a cast-iron arc of a circle about 85 feet diameter nicely planed. The arc is composed of pieces 5 feet long, each adjusted independently in the meridian by the transit instrument, and secured to massive stonework. The horizontal axis of the great universal joint gives motion to an index which points to polar distances on an arc of 6 feet radius, by which the telescope is very quickly set in polar distance. A 20-inch circle with a very delicate level, attached to the telescope, performs the same office, more slowly but with greater accuracy; and also gives polar distances with considerable precision when duly corrected. The whole mounting was planned especially with a view of carrying on a regular system of sweeping, for which it is peculiarly adapted; but the known objects which require examination are so numerous that hitherto we have been fully occupied with them; and the discovery of new nebulæ has as yet formed no part of the systematic work of the observatory.

As yet the telescope is not provided with a clock movement. A clock movement was part of the original design, and there would have been no serious difficulty in carrying it out; but the want of it has not been very much felt, and there were other matters requiring more immediate attention.

Various micrometers have been tried, but upon the whole the common wire micrometer with thick lines succeeds the best. The thick lines are formed by coiling very fine silver wire four times round the forks, soldering it there, and then removing the lower half of the coil. A little spirit varnish unites the fine wires into a thin ribbon with a straight edge, perhaps as perfect as can be made. The micrometer is used without illumination; and I have never failed to see the lines in the darkest night; but of course measurements with thick lines are inferior in point of accuracy to measurements with thin lines in an illuminated field. Unfortunately any micrometrical contrivance which either diminishes the light of the telescope, or renders the field less dark, extinguishes the faint details of the nebulæ, which even with an aperture of 6 feet are often barely perceptible. There have been many ingenious attempts to make fine lines visible in a perfectly dark field, but they have not, at least as far as my experience goes, been entirely successful.

The telescope has two specula, one about three and a half, and the other a little more than four tons weight. Each speculum was originally provided with a system of levers to afford it an equable support: it was placed upon this system before it was ground, and it has rested upon it ever since. The system of levers is a combination of three systems in every respect similar, resting on three points under the centres of gravity of the three equal sectors into which the speculum may be supposed to be

divided. Each system consists of one triangle with its point of support directly under its centre of gravity, upon which it freely oscillates. This triangle carries at its angles three similar points of support for three other triangles, under their centres of gravity, and they again at their angles carry in a similar way cast-iron platforms formed of thin ribs so as to make a kind of irregular open-work grating, supported under their centres of gravity. These platforms are all of equal area though not of similar shape. As there are three systems there are therefore twenty-seven platforms, which together make a circular disc about an inch in diameter less than the speculum: when arranged however a little apart so as not to touch, they make a disc about the same diameter as the speculum. Each platform is coated with greased cloth, and may be considered as bearing up one twenty-seventh of the weight of the speculum. Between the platforms and the speculum pieces of tin plate are inserted to diminish the friction as much as possible. The platforms being of open-work, they do not prevent the water in which the speculum is immersed from freely carrying away the heat as it is developed during the process of polishing, which is essential.

It is evident that a speculum so supported will be practically free from strain while in a horizontal position, provided the due action of the levers is not interfered with by any disturbing force; it will be very much in the same condition as if floating in a vessel of mercury; when it ceases to be horizontal however new forces come into play: part of the weight must then be resisted by pressure against the edge. Four very strong segments of cast iron, each about one-eighth of the circumference, were adjusted to the edge by screws, the segments bearing upon the massive castings which sustained the three primary supports of the lever apparatus. Provision was made to allow a little motion perpendicular to the plane of the speculum, to guard as much as possible against strain from the elasticity of the lever apparatus, which was however very small, the yielding being less than one-fortieth of an inch.

The two specula of 3 feet aperture I have so long employed are mounted on a similar principle: they have however fewer points of support, and by a little sacrifice of the condition of perfect equilibrium, the whole system of levers was thrown without difficulty almost exactly into one plane. They are free from perceptible flexure in the different positions of the instrument. With the two specula of 6 feet diameter the case was otherwise. The 3-feet specula, weighing each about thirteen hundred weight, were very much stiffer, in proportion to their weight, than the 6-feet specula. To have made the 6-feet specula of equal proportionate stiffness, either they should have been enormously heavy, or the material should have been so disposed as to give greater stiffness than when simply cast into the shape of a solid disc. Some years ago it was ascertained by experiments, but on a small scale, that it would be practicable to dispose of three-fourths of the material of a speculum so as to secure a great increase of stiffness; the form adopted was a system of hexagonal cells. Whether on a great scale the difficulties would be too serious to be surmounted is a question; however it is with solid discs we have had to deal. The relative stiffness of

speculum metal and wrought iron is about five to six three-tenths ; yet strange as it may appear, so delicate is the optical test, that strong pressure of the hand at the back of a speculum, four tons weight, and nearly six inches thick, produces flexure sufficient to distort the image of a star. It is obvious, therefore, that a slight inequality in the action of the lever apparatus supporting a 6-feet speculum would produce an amount of flexure sufficient to destroy definition. It has not been found possible so to secure the 6-feet specula as to prevent a slight change of place in a plane parallel to the plane of the levers, and as the levers are not all in one plane as in the case of the 3-feet specula, and a considerable amount of friction exists between the speculum and its lever supports, when the speculum changes place, however slightly, there will be a force tending to disturb the equal actions of the levers. It has been found that when the speculum changes its place one-thirtieth of an inch, still adhering to its levers, unmistakeable distortion will be produced. We have occasionally observed, even during a night's work, the sudden appearance, and the as sudden disappearance of the rudiments of focal lines, the undoubted evidences of flexure ; but we have not found that flexure, even to the extent of materially disfiguring the image of a large star, interferes much with the action of the speculum on the faint details of nebulæ, although it greatly lessens its power in bringing out minute points of light, and in showing resolvability where under favourable circumstances resolution had been previously effected.

In the spring of 1848 the heavier of the two specula for nearly three months performed admirably, very rarely exhibiting the slightest indication of flexure. It then remained inactive for some time before and after the solstice, and when we again commenced observing it was found to be in a state of strain ; the friction between the lever apparatus and the speculum had no doubt in the meantime increased considerably, and the levers being therefore unable to adjust themselves to some slight but permanent change in the place of the speculum, they no longer supported it equably. It was cautiously raised a little by screws for the purpose of re-adjusting the levers, and to our surprise the unequal strain of the screws was found to have produced permanent flexure, so that the speculum did not again perform well till after it had been reground. From the experiments of Mr. EATON HODGKINSON and others, we should have been prepared for a change of figure in a mass of cast iron, but with a material so brittle and so elastic as speculum metal, the result was quite unexpected. Recently, in supporting the lighter of the two specula, twenty-seven triangles have been substituted for the twenty-seven platforms, each triangle carrying at its angles three brass balls, so that the speculum rolls freely on eighty-one balls, which support it pretty nearly equably. This appears to be a great improvement, but I will not dwell further on the subject. To describe the experiments which have been made with a view of discovering the best means of supporting very large specula, a question of great theoretical and practical difficulty, would occupy too much space, and would require elaborate engravings ; it would besides be foreign to the object of this paper.

The same considerations also forbid any more minute description of the telescope and its mounting.

From what has been said, it is evident that the 6-feet specula being occasionally in a state of strain, were not uniform in their action. There was however another cause of unequal action. The 6-feet specula, after they have been polished, cannot be tested till they have been removed from the laboratory to the telescope, there to await a good night, the great focal length making it impossible to test them while on the engine. Now it has often happened that a speculum which has subsequently proved to be incapable of very fine definition, has remained in the telescope during a succession of moderately good nights, when a great deal of work was done, awaiting a night when the air was in a state to warrant a decisive opinion. Such a speculum might do good work, but it would not resolve difficult nebulæ, neither would it bring out faint points of light, even when wide apart. There is still another cause of the unequal action of our specula far more serious, the varying state of the atmosphere. When the air is unsteady, minute stars are no longer points, the diffused image is much fainter, and single stars, easily seen when the air is steady, are no longer visible. When many minute stars are crowded together the whole become blended, and instead of a resolved nebula we have merely a diffused, perhaps bright nebulosity. The transparency of the air varies also quite as much; and the aspect of the nebulæ changes from night to night, just as the appearance of a distant building alters as the details of the architecture are more or less obscured by the intervening mist. With these facts, the Society will not be surprised should it be in our power at a future time to communicate some additional particulars, even as to the nebulæ which have been the most frequently observed.

The sketches which accompany this paper are on a very small scale, but they are sufficient to convey a pretty accurate idea of the peculiarities of structure which have gradually become known to us: in many of the nebulæ they are very remarkable, and seem even to indicate the presence of dynamical laws we may perhaps fancy to be almost within our grasp. To have made full-sized copies of the original sketches would have been useless, as many micrometrical measures are still wanting, and there are many matters of detail to be worked in before they will be entitled to rank as astronomical records, to be referred to as evidence of change, should there hereafter be any reason to suspect it.

Much however as the discovery of these strange forms may be calculated to excite our curiosity, and to awaken an intense desire to learn something of the laws which give order to these wonderful systems, as yet, I think, we have no fair ground even for plausible conjecture; and as observations have accumulated the subject has become, to my mind at least, more mysterious and more inapproachable. There has therefore been little temptation to indulge in speculation, and consequently there can have been but little danger of bias in seeking for the facts. When certain phenomena can only be seen with great difficulty, the eye may imperceptibly be in some

degree influenced by the mind; therefore a preconceived theory may mislead, and speculations are not without danger. On the other hand, speculations may render important service by directing attention to phenomena which otherwise would escape observation, just as we are sometimes enabled to recognize a faint object with a small instrument, having had our attention previously directed to it by an instrument of greater power. The conjectures therefore of men of science are always to be invited as aids during the active prosecution of research.

It will be at once remarked, that the spiral arrangement so strongly developed in Plate XXXV. H. 1622, 51 MESSIER, fig. 1, is traceable, more or less distinctly, in several of the sketches. More frequently indeed there is a nearer approach to a kind of irregular interrupted annular disposition of the luminous material than to the regularity so striking in 51 MESSIER; but it can scarcely be doubted that these nebulæ are systems of a very similar nature, seen more or less perfectly, and variously placed to the line of sight. In general the details which characterize objects of this class are extremely faint, scarcely perhaps to be seen with certainty on a moderately good night with less than the full aperture of 6 feet: in 51 MESSIER, however, and perhaps a few more, it is not so. A 6-feet aperture so strikingly brings out the characteristic features of 51 MESSIER, that I think considerably less power would suffice, on a very fine night, to bring out the principal convolutions. This nebula has been seen by a great many visitors, and its general resemblance to the sketch at once recognized even by unpractised eyes. MESSIER describes this object as a double nebula without stars; Sir WILLIAM HERSCHEL as a bright round nebula, surrounded by a halo or glory at a distance from it, and accompanied by a companion; and Sir JOHN HERSCHEL observed the partial subdivision of the *s.f.* limb of the ring into two branches. Taking Sir J. HERSCHEL's figure, and placing it as it would be if seen with a Newtonian telescope, we shall at once recognise the bright convolutions of the spiral, which were seen by him as a divided ring. We thus observe, that with each successive increase of optical power, the structure has become more complicated and more unlike anything which we could picture to ourselves as the result of any form of dynamical law, of which we find a counterpart in our system. The connection of the companion with the greater nebula, of which there is not the least doubt, and in the way represented in the sketch, adds, as it appears to me, if possible, to the difficulty of forming any conceivable hypothesis. That such a system should exist, without internal movement, seems to be in the highest degree improbable: we may possibly aid our conceptions by coupling with the idea of motion that of a resisting medium; but we cannot regard such a system in any way as a case of mere statical equilibrium. Measurements therefore are of the highest interest, but unfortunately they are attended with great difficulties. Measurements of the points of maximum brightness in the motling of the different convolutions must necessarily be very loose; for although on the finest nights we see them breaking up into stars, the exceedingly minute stars cannot be seen steadily, and to identify one in each case would be im-

possible with our present means. The nebula itself, however, is pretty well studded with stars, which can be distinctly seen of various sizes, and of a few of these, with reference to the principal nucleus, measurements were taken by my assistant, Mr. JOHNSTONE STONEY, in the spring of 1849, during my absence in London; for some time before the weather had been continually cloudy. These measurements have been again repeated by him this year, 1850, during the months of April and May. Just as was the case last year, in February and March the sky was almost constantly overcast. He has also taken some measures from the centre of the principal nucleus to the apparent boundary of the coils, in different angles of position. The micrometer employed was furnished with broad lines formed of a coil of silver wire in the way I have described, seen without illumination. Some of the stars in the nebula are so bright, I have little doubt they would bear illumination; if so, their positions with respect to some one star might be obtained with great accuracy of course by employing spiders' lines; this season however it is too late to make the attempt. Several of these stars are no doubt within the reach of the great instruments at Pulkova and at Cambridge, U.S., and I hope the distinguished astronomers who have charge of them will consider the subject worthy of their attention. Their better climate gives them many advantages, of which not the least is the opportunity of devoting time to measurements without any serious interruption to other work. I need perhaps hardly add, that measurements taken from the estimated centre of a nucleus, and still more from the estimated termination of nebulosity, are but the roughest approximations; they are however the only measurements nebulosity admits of, and if sufficiently numerous, I think they will bring to light any considerable change of place, or form, which may occur.

The spiral arrangement of 51 MESSIER was detected in the spring of 1845. In the following spring an arrangement, also spiral but of a different character, was detected in 99 MESSIER, Plate XXXV. fig. 2. This object is also easily seen, and probably a smaller instrument, under favourable circumstances, would show everything in the sketch. Numbers 3239 and 2370 of HERSCHEL'S Southern Catalogue are very probably objects of a similar character, and as the same instrument does not seem to have revealed any trace of the form of 99 MESSIER, they are no doubt much more conspicuous. It is not therefore unreasonable to hope, that whenever the southern hemisphere shall be re-examined with instruments of great power, these two remarkable nebulae will yield some interesting result.

The other spiral nebulae discovered up to the present time are comparatively difficult to be seen, and the full power of the instrument is required, at least in our climate, to bring out the details. It should be observed that we are in the habit of calling all objects spirals in which we have detected a curvilinear arrangement not consisting of regular re-entering curves; it is convenient to class them under a common name, though we have not the means of proving that they are similar systems. They at present amount to fourteen, four of which have been discovered this spring; there are besides other nebulae in which indications of the same character have been

observed, but they are still marked doubtful in our working list, having been seen when the air was not very transparent; 51 MESSIER, Plate XXXV. fig. 1, is the most conspicuous object of that class.

The question may perhaps suggest itself whether there is not something in the aspect of a spiral nebula, which forces upon us the conviction that it is a system with an organization quite different from that of any known cluster. The only answer I am enabled to give to that question is, that in the exterior stars of some clusters there appears to be a tendency to an arrangement in curved branches, which cannot well be unreal, or accidental. Nos. 480, 1916, 1968, 1972, are the objects in which I observe that peculiarity noted down in our list of observations as suspected. As to 1968, Sir JOHN HERSCHEL uses the following words in his Catalogue, "has hairy-looking curvilinear branches." Careful drawings based on measurements would settle the question, whether the suspected curvilinear distribution of the stars is real or not; this would also perhaps settle another question of interest, whether the distribution of the stars in these objects is reconcilable with the hypothesis of an equal distribution of the stars of the system; as yet however there has not been time to make the required measurements. In passing from the spiral to the regular annular nebulae, we perceive we are at once engaged with objects of a very different character: still here even there seems to be something like a connecting link; the great round planetary nebula, H 838, Plate XXXVII. fig. 11, with a double perforation appears to partake of the structure both of the annular and spiral nebulae. There were but two annular nebulae known in the northern hemisphere when Sir JOHN HERSCHEL's Catalogue was published; now there are seven, as we have found that five of the planetary nebulae are really annular. Of these objects, the annular nebula in Lyra is the one in which the form is by far the most easily recognized. I have not yet sketched it with the 6-foot instrument, because I have never seen it under favourable circumstances: the opportunities of observing it well on the meridian are comparatively rare owing to twilight. It was however observed seven times in 1848 and once in 1849. The only additional particulars I collect from the observations, are that the central opening has considerably more nebulosity in it than it appeared to have with the 3-foot instrument, and that there is one pretty bright star in it, *s. f.* the centre, and a few other very minute stars. In the sky round the nebula and near it there are several very small stars which were not before seen, and therefore the stars in the dark opening may possibly be merely accidental. In the annulus, especially at the extremities of the minor axis, there are several minute stars, but there was still much nebulosity not seen as distinct stars.

The other annular nebula of HERSCHEL's Northern Catalogue is a much fainter object: it has been observed but once with the large instrument, August 1, 1848; but the evidence of resolution appears to have been more complete; many stars were seen in the annulus; one of them was very conspicuous. That a faint nebula should be more easily resolvable than a bright one is not unusual, neither is it contrary to probability; faintness may be owing to distance, or to a wider separation of the stars,

either physically or optically; in the latter case it is not unlikely that in a faint nebula they might be seen separate with an instrument of great aperture, while in the brighter and more closely packed nebula they were blended together, owing to imperfect definition, arising out of the state of the air, or instrument. As an example, the dumb-bell is a bright nebula: on three exceedingly fine nights succeeding each other at short intervals, the stars in the brighter parts of the nebula were better shown with 3 feet aperture than they have since been with 6 feet. Very fine nights, when the air seems to set no limits to magnifying power, are extremely rare, and the dumb-bell has not been seen with the great instrument on such nights. On the other hand, on all ordinary nights, a variety of details are shown by the great instrument which were not seen on the finest nights with the smaller instrument. There is another fact I may perhaps add, that while high magnifying power brings out minute stars it extinguishes faint nebulosity. The optical reason is obvious; but in sketching the dumb-bell nebula in 1845 that fact was overlooked, and but one eye-piece was used, a very high one; had there been a low one also used the sketch would have been more complete. To return to the annular nebulæ. The five planetary nebulæ we have ascertained to be annular, are as follows: 464, Plate XXXVIII. fig. 12, has two stars within it; 2075 has one star a little following the centre; 2241, Plate XXXVIII. fig. 13, has no star, but is surrounded with a faint external annulus; 2050 has a perforation not round nor quite symmetrical with the star; 838, Plate XXXVII. fig. 11, has two stars and two perforations. In no instance is the central opening quite dark. The planetary nebula, 2047, is marked in our journal as annular, but the observation is without date and other particulars, and therefore I do not consider it altogether trustworthy. In 2098, Plate XXXVIII. fig. 14, another planetary nebula, we have not detected any perforation, but it has ansæ, which probably indicate a surrounding nebulous ring seen edgewise, just as 450, Plate XXXVIII. fig. 15, has apparently a nebulous ring seen on the flat; and if the annular nebulæ are really hollow shells, the nebulous ring would cover the comparatively transparent centre; 365 and 2037 have never been observed.

Passing from the annular nebulæ to the nebulous stars, there are two objects well-worthy of especial notice.

Sir JOHN HERSCHEL very accurately describes a nebulous star thus:—"A sharp and brilliant star concentrically surrounded by a perfectly circular disc or atmosphere of faint light, in some cases dying away insensibly on all sides, in others almost suddenly terminated*." No. 450 of Sir JOHN HERSCHEL's Catalogue is one of these nebulous stars, and is there thus described:—"A star of the 8th magnitude, exactly in the centre of an exactly round and bright atmosphere, 25" diameter. The star is quite stellar, not a mere nucleus. Another star, 8th magnitude, distant 100", and about 85° n p, has no such atmosphere.—A most remarkable object."

Plate XXXVIII. fig. 15 represents this wonderful object as seen with the 6-feet telescope. It has been several times examined, and as yet we have not seen the

* Outlines of Astronomy, p. 605.

slightest indication of resolvability. The outer ring is seen on a pretty good night completely separated from the nucleus surrounding the brilliant point or star. The light is very bright, and always appeared to be flickering, owing no doubt to the unsteadiness of the atmosphere. There is a small dark space to the right of the star, which indicates a perforation similar perhaps to that discovered in Nos. 838, 2050, and others. The annular form of this object was detected by Mr. JOHNSTONE STONEY, my assistant, when observing alone, and the sketch is his; I have however since had ample opportunities of satisfying myself that the object has been accurately represented. Plate XXXVIII. fig. 16 represents the other nebulous star, ι Orionis: the remarkable feature in this object, the dark cavity, not symmetrical with the star, was also discovered by Mr. JOHNSTONE STONEY when observing alone with the 3-feet telescope: I have since seen it several times and sketched it. The components of ι Orionis have not been laid down micrometrically, or even with care by the eye, but the dark cavity with respect to the stars is faithfully represented. If the dark cavity was symmetrical with the stars, it might perhaps be thought by some that the phenomenon was optical, but as it is the thing is impossible. A small double star $n f$ has similar openings, but they are not so easily seen. These openings appear to be of the same character as the opening within the bright stars of the trapezium of Orion, the stars being at the edges of the opening. Had the stars been situated all together within the openings, the suspicion would perhaps have suggested itself more strongly that the nebula had been absorbed by the stars. As it is, I think we can hardly fail to conclude that the nebula is in some way connected with these bright stars, in fact that they are equidistant, and therefore, if the inquiries about parallax, now proceeding with so much activity, should result in giving us the distances of these bright stars, we shall have the distance of this nebula.

The long elliptic or lenticular nebulæ are very numerous; I have given three sketches of remarkable objects of this class: the appearance of Plate XXXVII. fig. 7 suggests the idea of an elliptic annular system seen very obliquely. A series of very elliptic shells enveloping the nucleus, seen somewhat obliquely, would perhaps also present the same aspect. The dark chink in Plate XXXVII. fig. 8 might indicate either a real opening, the system being an elliptic ring, or merely a line of comparative darkness, the section through the axis of a very long narrow elliptic shell. In Plate XXXVII. fig. 9 there is a well-marked stratification, which might possibly be the appearance, Plate XXXVII. fig. 7, on the first supposition, would present if seen in another direction. It is to be hoped that as observations multiply, and these extraordinary objects which abound in the heavens are seen in various directions, we shall gradually become acquainted with their real form. At present further conjectures would be to no purpose.

The remaining sketch, Plate XXXVIII. fig. 17, is the dumb-bell nebula as seen with the 6-feet telescope: the sketch is by Mr. JOHNSTONE STONEY, and the form of the nebulosity and its various gradations of intensity have been represented with considerable fidelity. There was no subsequent opportunity of marking in the stars,

and therefore they have been inserted at random to complete the general effect, and many minute details are still wanting to make the figure complete.

As we have proceeded with our task of re-examining Sir JOHN HERSCHEL's Catalogue, several groups of nebulæ have been discovered, although new objects have not been as yet sought for. In some cases a nebulous connection has been detected between the individuals of the group, in others not. Sketches have been made and some measures taken. The whole subject of the grouped or knotted nebulæ is one of deep interest; but we have not proceeded sufficiently far with it to make it worth while to enter upon it in the present paper, and it only remains to point out a defect common to all the sketches which might mislead if not specially noticed. In sketching we necessarily employ the smallest amount of light possible, very feeble lamp-light, especially where the objects or their details are of the last degree of faintness. To see the sketch as we proceed it is often necessary to mark it too strongly: this would be of little moment if the excess of colour was always in the same proportion, especially as different eyes form a very different estimate of the relative intensities of a nebula and its representation on paper, but it is not so; the contrast between the faint and bright nebulæ and between the faint and bright parts of the same nebula is very liable to be made too slight. The most important error to guard against is that of supposing that the well-marked confines of the nebula on paper really represent the boundaries of the object in space in all cases. Frequently there is a very gradual fading away at the edge, the last trace of which is either a luminous mist becoming rarer till imperceptible; a gauge-like tissue of the faintish imaginary flocculi, or hairy filaments, which become finer and more scattered till they cease to be visible, showing that the real boundary has not been seen, and that the form of the object would alter if additional optical power could be brought to bear upon it. The same remark applies to the faint interior details, in most cases probably only in part seen.

Plate XXXV. figs. 1 and 2 are seen on a scale of half an inch to a minute; the others are on no regular scale: they are about the size of the figures which accompany Sir JOHN HERSCHEL's Catalogue, the smaller however have been somewhat enlarged where there were details which otherwise could not have been well represented.

Annexed are a few remarks relating to each figure, which seem to make the information conveyed by it more complete: they are for the most part extracts selected from our journal of observations; in a few cases, however, to save space, merely the substance is given.

Where the 3-feet instrument was employed it is specially mentioned; in every other case it was the 6-feet instrument.

Plate XXXV. fig. 1, H. 1622.—This object has been observed twenty-eight times with the 6-feet instrument; it had been repeatedly observed previously with the 3-feet instrument.

September 18, 1843.—Observed with the 3-feet instrument; power single lens,

1-inch focus; a great number of stars clearly visible in it, still HERSCHEL's rings not apparent, at least no such uniformity as he represents in his drawing.

April 11, 1844.—Observed with the 3-feet instrument, two friends assisting; both saw centre clearly resolved.

April 26, 1848.—6-feet instrument. Saw the spirality of the principal nucleus very plainly; saw also spiral arrangement in the smaller nucleus.

The following measurements were taken by my assistant, Mr. JOHNSTONE STONEY, in the spring of 1849 and 1850.

	Mean of the observations of position.	No. of observations.	Greatest difference between observations and the mean.	Mean of the observations of distance.	No. of observations.	Greatest difference between observations and the mean.
N. <i>n</i> .	16 34'	4	3 27'	4 22.2	4	9.6
N. 1.	52 4	1	.....	2 6.6	1	
N. 2.	54 0	4	1 57	5 0.0	4	5.4
N. 3.	104 20	2	2 3	2 45.6	2	3.6
N. 4.	111 57	2	0 40	4 3.6	2	0.6
N. 5.	165 35	2	0 31	1 43.2	2	1.1
N. 6.	191 42	1	.....	3 54.0	1	
N. 7.	211 2	1	.....	2 36.6	1	
N. 7, 8.	270 42	1	.....	0 34.8	1	
N. 9.	231 32	4	3 35	1 23.4	3	6.6
N. 9, 10.	197 57	1	.....	0 27.0	1	
N. 11.	279 21	4	4 18	1 49.8	3	22.2
N. 11, 12.	225 27	1	.....	0 12.6	1	
N. 13.	281 37	2	0 22	3 59.0	1	
N. 14, 15.	297 15	1				
N. 15.	310 34	4	4 17	2 55.8	4	13.8
N. α	5 7	...	.....	3 22.8	2	0.1
N. β				1 28.2	3	3.0
N. γ				2 37.8	3	2.4
N. δ				1 46.2	1	
N. ϵ	95 7	...	.....	2 46.8	1	
N. ζ				1 40.8	1	
N. η				3 15.6	1	

Observations.—There is a great discrepancy between the measured position of 11 and 12 and the rough diagram made at the time of observation.

N. 13 is twice noticed in the observing-book.

Once N. 11, 13 is taken as one position; the other times N. 11 and 13 are taken separately, N. 13 being made $1^{\circ} 40'$ less than N. 11; hence $270^{\circ} 31'$ is a more probable position for N. 13 than that given in the Table.

The Greek letters are perpendiculars from N. on tangents to the outsides of the convolutions, the tangents from α, β, γ being vertical, that is, parallel to the position $95^{\circ} 7'$, and those for $\delta, \epsilon, \zeta, \eta$ horizontal, *i. e.* parallel to position $5^{\circ} 7'$.

The greater part of the observations were made when the eye was affected by lamp-light, which made it difficult to estimate correctly the centre of the nucleus; it was of importance that no time should be unnecessarily spent, and after the lamp had been used a new measure was taken, as it was judged that the object was sufficiently seen. With the brighter stars this would frequently happen before the nucleus was

well defined, as all impediments to vision seem to affect nebulæ much more than stars the light of which would be estimated as of the same intensity. In the foregoing list the greatest discrepancies are in the measures of bright objects, and this is probably the proper account of it. No stars have been inserted in the sketch which are not in the table of measurements. The general appearance of the object would have been better given if the minute stars had been put in from the eye-sketch, but it would have created confusion.

Plate XXXV. fig. 2, H. 1173.—This nebula has been repeatedly observed with the 6-feet instrument.

March 11, 1848.—Spiral with a bright star above; a thin portion of the nebula reaches across this star and some distance past it. Principal spiral at the bottom, and turning towards the right.

March 20, 1848.—Spirality very evident, though night bad: nebula not traced to upper star.

April 16, 1849.—Took measures of the stars 1, 2.

April 17, 1849.—Took measures of the stars 1, 2, 3, 4 from the nucleus; they are as follows:—

No.	Mean of observations of position from north in direction <i>n. f. s. p.</i>	No. of observations.	Greatest difference between mean and observation.	Mean of observations of distance.	No. of observations.	Greatest difference between mean and observation.
1.	34 1	1	.....	2 54.6	2	9.6
2.	80 35	2	0 18	1 46.3	3	14.4
3.	117 3	3	0 23	1 48.4	4	13 6
4.	177 57	1	.....	2 48.1	1	

Three very minute stars in the eye-sketch have not been inserted, not having been measured.

Plate XXXVI. fig. 3, H. 604.—This nebula was observed frequently with the 3-feet instrument, but nothing remarkable seems to have been made out, except the resolvable character of the nucleus. It was first observed with the great telescope, March 24, 1846, and a tendency to an annular or spiral arrangement discovered; night bad; March 5, 1848, sketched.

March 9, 1848.—“Night excellent, a spiral seen in an oblique direction, resolved well, particularly towards the centre, where it is very bright; Dr. ROBINSON observing.” Observed March 3, 1850; badly seen.

With the single exception of March 3, 1850, we have unfortunately no recent observation of this extraordinary object: it has been passed over, because to observe it, except on a very fine night, would be waste of time.

Plate XXXVI. fig. 4, H. 2205.—Observed frequently, and by many friends. The drawing represents the object with considerable accuracy.

“September 10, 1849.—Spiral, but query whether this is not more properly an annular than a spiral nebula.”

The details are faint, but can be seen on any moderately fine night.

Plate XXXVI. fig. 5, H. 131.—This figure represents the central portion of a very large nebula. The nebula itself has not been sufficiently examined, but as yet no other portion appears to have a spiral, or indeed any regular arrangement. The sketch is not very accurate, but represents sufficiently well the general character of the central portion.

“September 6, 1849.—A spiral.

“September 16, 1849.—New spiral; α the brightest branch; γ faint; δ short but pretty bright; β pretty distinct; ϵ but suspected; the whole involved in faint nebula, which probably extends past several knots which lie about it in different directions. Faint nebula seems to extend very far following: drawing taken.

“September 10, 1849.—An attempt at a drawing taken: fog.

“October 1849.—The whole nebula in flocculi.”

Plate XXXVII. fig. 6, H. 444.—“December 19, 1848.—Bright star between; tails and curved filaments; perhaps annulus around the two nebulae.

“December 22, 1848.—Sketch made.

“February 11, 1849.—Lower streak seems to reach the filaments of right-hand nucleus.”

Plate XXXVII. fig. 7, H. 854.—“March 31, 1848.—A curious nebula with a bright nucleus; resolvable; a spiral or annular arrangement about it; no other portion of the nebula resolved. Observed April 1, 1848, and April 3, with the same results.”

Plate XXXVII. fig. 8, H. 1909.—“April 27, 1848.—A very bright resolvable nebula, but none of the component stars to be seen distinctly even with a power of a thousand. A perfectly straight and longitudinal division in the direction of the major axis. Resolvability most strongly indicated towards the nucleus.

“May 2, 1848.—Not seen so well as on April 27. Darkness in the middle, along the major axis barely visible.

“April 1849.—A long ray elliptical. Major axis perhaps eight times minor axis. Surface somewhat broken up, and a slight darkness in the direction of the major axis: night indifferent: at intervals a few stars faintly perceptible.”

Plate XXXVII. fig. 9, H. 1397.—This sketch was made with great care by my assistant, Mr. JOHNSTONE STONEY, and I have no doubt it is very accurate. Observed and sketched, April 19, 1849. It had been previously observed, March 26, 1848, by my former assistant, Mr. RAMBAUT, and I find the following note by him:—“A most extraordinary object, masses of light appear through it in knots.”

Plate XXXVII. fig. 10, H. 399.—Observed December 22, 1848, February 11, 1849, and January 16, 1850, when the drawing was taken. The two comparatively dark spaces, one near the vertex and the other near the base of the cone, are very remarkable.

Plate XXXVII. fig. 11, H. 838.—September 27, 1843.—(3-feet telescope.) Night pretty good; a star in the centre and apparently ragged outline.

March 7, 1848.—(6-feet telescope).—Night bad : aurora. Darkness in the centre ; star not certainly seen ; outline ragged.

March 11, 1848.—Seen by Dr. ROBINSON and my former assistant, Mr. RAMBAUT ; sketch made of it. "Two stars considerably apart in the central region ; dark penumbra around each spiral arrangement, with stars as apparent centres of attraction ; stars sparkling in it, resolvable ; night excellent." Note by Mr. RAMBAUT : "March 5, 1848.—Saw two dark and very large spots in the middle ; Lord Rosse remarked that all round its edge the sky appeared darker than the average."

"March 11, 1848.—Remarkably fine night ; a brilliant star in the centre ; also star to the right ; round each a black space (see sketch)." Note by Mr. RAMBAUT : "March 25, 1848.—Air steady, but slight haze ; large star visible. Only at one clear interval could I get a glimpse of the spiral arrangement of this nebula, which I should have totally overlooked had I not seen it so plainly on a former occasion."

"March 26, 1848.—Second bright star visible ; spiral arrangement hardly perceptible ; not seen so well as on the 11th of March."

"March 27, 1848.—Not seen so well as last night ; second star seen at rare intervals, power 468."

"March 28, 1848.—Night hazy, could not see second star."

"March 31, 1848.—Caught one glimpse of second star, but saw the large star very plainly."

"April 1, 1848.—Night hazy ; spiral arrangement little more than suspected ; nebula very faint."

"April 3, 1848.—Small star distinctly seen ; spirals tolerably well brought out ; hazy, but air steady."

"April 6, 1848.—First star seen easily, though hazy ; the second only occasionally ; spiral arrangement hardly discernible."

"January 1850.—Seen very imperfectly ; only one of the stars seen."

"March 9, 1850.—Second star only seen for a moment." Several attempts were made to procure measures of position and distance of the two stars this spring, but in vain, the season was so unfavourable. In 1848, the micrometer requiring illumination, no attempt was made. With the micrometer as at present mounted there would not have been the slightest difficulty in procuring measures.

Fig. 12, H. 464.—"Annular nebula at the edge of the cluster M. 46. Sketched December 22, 1848 annular, two stars in it."

"January 27, 1849.—A third star suspected in brightest part."

"January 29, 1849.—Third star strongly suspected."

"February 13, 1849.—Observed, nothing further."

"March 16, 1849.—Saw but two stars in it."

Fig. 13, H. 2241.—"October 31, 1848.—Has a central spot, at moments very dark."

"December 13, 1848.—Nothing more, except perhaps that faint external annulus extends further than had been seen before."

"December 14, 1848.—Note by Mr. JOHNSTONE STONEY:—'Three stars near it, somewhat in this fashion; showed it to Sir JAMES SOUTH.'

"December 16, 1848.—Sketches made by Lord Rosse and Mr. JOHNSTONE STONEY.

"December 19, 1848.—Drawing confirmed."

Fig. H. 14, 2098.—"Observed October 23, 1848, and sketch made.

"October 25, 1848.—Sketch confirmed.

"August 16, 1849.—Position of ring taken with an eye-piece furnished with a level and a position circle. Inclination of ring to horizon 9° ."

Fig. 15, H. 450.—"February 20, 1849.—Most astonishing. The star perhaps a little nearer the *np* edge. Drawing made; breadth of ring less on *f* side.

"February 22, 1849.—Observed again; dark space to the right of star.

"January 16, 1850.—Observed; examined with the 700 and 900 eye-pieces; both the dark and the bright rings seemed unequal in breadth; the light appeared unsteady and flickering. The night was rather foggy, but the sky black."

Fig. 16, H. 361.—"January 28, 1849.—Orionis. Dark space in the nebula containing nearest companion; light nearly equable; sketch made; 3-feet telescope employed. All the stars in the neighbourhood are nebulous, of these two a little *sp*, last seem to have dark spaces as in figure. To the *nf* of this there is another smaller double star, suspected to have similar dark spaces to Orionis.

"February 16, 1849.—Three-feet telescope confirmed observation of January 28, 1849.

"March 17, 1849.—Large triple star to south of nebula Orionis; confirmed observation of opening in its atmosphere, also the openings at double star *sp* last."

Fig. 17, H. 2060.—"Observed September 9, 1849. Drawing commenced.

"September 16, 1849.—Drawing proceeded with; examined also with 3-feet telescope to find if any evidence of change since drawing in Philosophical Transactions was taken; none decisive."

List of some remarkable Nebulæ.

Spiral or curvilinear.

H. 142, 262, 327, 695, 749, 910, 1002, 1211, 1312, 1368, 1451, 1570, 1776, 2172.

With dark spaces.

264, 368, 491, 514, 692, 731, 788, 857, 887, 1107, 1225, 1909, 2241.

Ray with split.

1041, 1149, 1357.

Knotted nebulæ.

84, 257, 320, 409, 446, 581, 1274, 1901.

XXVI. *On the Structure and Use of the Ligamentum Rotundum Uteri, with some observations upon the change which takes place in the Structure of the Uterus during Utero-gestation.* By G. RAINEY, M.R.C.S., Demonstrator of Anatomy at St. Thomas's Hospital. Communicated by JOSEPH HENRY GREEN, Esq., F.R.S.

Received January 15,—Read April 11, 1850.

PRIOR to the discovery of the striated character of voluntary muscle, about 1765, by FONTANA, physiologists were unacquainted with any certain mark by which they could distinguish this variety of muscle from many other structures; and physiology being at that period in advance of anatomy, the question of the muscularity of many parts was obliged to be decided by their function instead of by their structure; but in the present state of minute anatomy, improved as it has been of late by the researches of microscopists, physiology and anatomy are made to move more in parallelism; this is especially the case with respect to the muscular system, so that if a muscle be made up of a bundle of fascicles of nearly equal size, and each one be marked transversely with parallel striæ, it is known to act either directly in obedience to the will, or to be capable of being called into operation through excito-motory influence, whilst a muscle consisting merely of an aggregation of fibres more or less distinctly nucleated, is known to act independently of the will; hence muscles are now named according to their function, voluntary and involuntary; or according to their structure, striped and unstriped. In the class of striped muscles physiologists are agreed to place the voluntary muscles, the upper part of the human œsophagus, and the heart; in that of unstriped ones, the muscular coat of the intestinal canal, the bladder, the uterus and round ligaments. As it respects the parts included in the latter division of this classification, I am obliged to dissent altogether in reference to the structure of the round ligaments of the uterus, having found in every subject in which I have examined them (the number being about a dozen) well-marked muscular fibres of the striped variety, in fact that they correspond in all respects to regular voluntary muscles: with this conviction I am desirous to communicate the result of my observations to the Royal Society. I may also add, that I have in my possession numerous preparations, microscopic as well as ordinary dissections, in which the accuracy of the facts stated in this paper are easily demonstrable.

The so-called round ligament of the uterus, regarded as a muscle, may be said to arise by three fasciculi of tendinous fibres; the inner one from the tendon of the internal oblique and transversalis near to the symphysis pubis, the middle one from the superior column of the external abdominal ring near to its upper part, and the

external fasciculus from the inferior column of the ring just above GIMBERNAT's ligament; from these attachments the fibres pass backwards and outwards, soon becoming fleshy; they then unite into a rounded cord, which crosses in front of the epigastric artery and behind the lower border of the internal oblique and transversalis muscles, from which it is separated by a thin fascia continuous with the fascia transversalis; it then gets between the layers of peritoneum forming the broad ligament of the uterus, along which it passes backwards, downwards, and inwards to the anterior and superior part of the uterus, into which its fibres, after spreading out a little, may be said to be inserted.

The striated muscular fibres are not confined merely to the surface of the round ligament, as if only accessory to some more important part of it, but they form almost the whole of its substance, and are more particularly distinct near to its centre; nor do they extend completely to the uterus, but after passing between the layers of the broad ligament to about the distance of an inch or an inch and a half from its superior part, they gradually lose their striated character, and degenerate into fasciculi of granular fibres mixed with long threads of fibro-cellular tissue. Plate XXXIX. fig. 1 is an accurate representation of some muscular fibres taken from the centre of the round ligament, where it is situated between the layers of the broad ligament, about one inch and a half from the uterus. Fig. 2 is also a representation of some muscular fibres taken from a part rather nearer to the uterus, showing the manner in which the striped muscular fibre terminates in the granular fibres above mentioned. This structure of the round ligaments is not, as might be expected, confined to the human species. In the Monkey these ligaments are composed almost entirely of striped muscular fibre, which extends all along them nearly as far as the uterus. The uterus in a monkey which I examined was very small, but the round ligaments were proportionally large: the primary fasciculi of muscular fibres were pale but very distinctly striated. In the Dog, as most probably in other animals in which the uterus divides into cornua extending into the abdomen considerably beyond the brim of the pelvis, the round ligaments, instead of passing downwards to be attached to the pelvis, as they are in the human subject, in whom the uterus is situated below its brim, pass from the extremities of the cornua of the uterus upwards, or rather forwards to the last rib. Hence in these instances, these ligaments, or rather muscles, may be said to arise from the last rib, and from the aponeurosis of the diaphragm, by a thin triangular expansion, partly tendinous, and partly muscular (the fibres of the muscle being pale but of the striped kind), and to be inserted into the cornua of the uterus, having the same relation to the Fallopian tubes and ligaments of the ovaries as in the animals which have a simple uterus. In the Sheep and the Cow the attachments of the round ligaments are similar to those in the Dog, and composed likewise of muscular fibres distinctly striated. Besides striped muscular fibres these ligaments contain numerous vessels, also some nerves and absorbents. The arterial trunks are large, but the capillaries into which they ultimately divide have the same size and arrangement as

those of ordinary muscle. The lymphatics are situated on the outer side of the ligament; their glands are sometimes of considerable length, and even pass through the external abdominal ring; connecting all these parts together, there is a considerable quantity of areolar tissue, especially where the striated muscular fibres are absent, or are about to terminate. In this part the detection of these fibres will be facilitated by examining the part in glycerine, which renders the fibro-cellular tissue more transparent without impairing in any considerable degree the distinctness of the striated muscle*. It is generally said that the round ligament passes through the external abdominal ring, and "is lost in the cellular tissue of the mons veneris and labia pudendi." It is true that the vessels supplying it, and a nerve, and some lymphatics, and frequently a gland, pass through the external abdominal ring, but the substance of the ligament is situated altogether above it so as in part to close it, and thus to tend very much to prevent the protrusion of intestine at this part, whilst it would facilitate its passage through the crural ring by directing it towards GIMBERNAT's ligament; hence probably the reason why females are more liable to femoral than to inguinal hernia.

Those who have written upon the office of the round ligaments of the uterus, regarding them either as made up of muscular fibres of the same kind as those of the uterus itself, or considering them as composed merely of "condensed cellular tissue," have considered their office, either as subservient to the process of utero-gestation, or as acting merely as mechanical supports to the uterus, that is, as uterine suspensory ligaments. Now the presence of voluntary (striped) muscular fibre in these so-called ligaments, proves that neither of these suppositions is correct, since striped or voluntary muscular fibre would be as unfit for the one purpose as it would be superfluous for the other; hence there can be but little doubt that these ligaments, or rather muscles, are concerned in some way or other with the act of copulation, rather than with those changes which are so slowly induced in the uterus during utero-gestation. Considering the position of the points of attachment of the round ligaments,

* Besides the structures just mentioned, these fibres are mixed with several pale, and much less distinctly striated ones, which resemble in all respects the tissue of the Dartos. The fibres of the Dartos are generally considered merely as fibro-cellular tissue, but they seem to possess characters by which they can be distinguished from other tissues. These fibres, both from the scrotum and the round ligament, the upper part especially, when examined by the microscope in water, appear to be made up of very fine threads of wavy fibre, mixed with extremely minute granules or molecules, by which their distinctness of outline is much obscured and rendered much less apparent than in the fibres of common areolar tissue; they are also more collected into bundles than is fibro-cellular tissue; but these same fibres, when examined in glycerine, become corrugated, resembling somewhat striped muscle; in some instances, indeed, the resemblance is so great, that it is difficult, if not impracticable, to distinguish between a bad specimen of striped muscular fibre and a good one of this tissue. Common fibro-cellular tissue is not corrugated by glycerine, but only rendered more transparent.

The distance to which the striped fibre extends towards the uterus, and the degree of its distinctness, differ very much in different subjects; in one subject I found it not more than an inch from the uterus. In the employment of glycerine to aid the detection of striped muscle and the corrugated tissue, it is sometimes necessary to allow these structures to remain in the glycerine a few minutes before its full effect is produced.

and the direction of their fibres, it is evident that their combined action will bring the uterus nearer to the symphysis pubis, and thus tend to draw it somewhat from the vagina, in this way increasing the length of the latter. Now the only way in which I can imagine that these changes in the position of these parts assist in sexual intercourse, is by their causing the semen to be attracted more into the upper part of the vagina and vicinity of the os uteri. [Since the communication of this paper to the Royal Society I have been informed that this opinion is not new, but that this view of the use of the round ligament had been published by M. VELPEAU*, and that it is also partly in accordance with that of MAYGRIERS†.] This supposition seems to accord with the position and attachments of the round ligaments in those animals in which the uterus extends into the cavity of the abdomen beyond the brim of the pelvis, as was noticed in the Dog, the Sheep and the Cow, where their action would, obviously, be the same in drawing the uterus from the vagina, and in tending to elongate the latter, as in the human subject in whom the angles of the uterus are below the level of the broad ligaments. In such an act the muscular fibres of the round ligaments could scarcely be said to be voluntary; but still they would be as much so as the other muscles concerned in the same process, that is, as those of the male organs of generation. In these instances muscles are said to act under excitatory influence, but muscles which are thus excited have the same structure as those more obviously under the control of the will, namely, striped fibres.

Some observations upon the change which takes place in the Structure of the Uterus during Utero-gestation.

The fasciculi of fibres composing the upper part of the round ligament separate as they approach the fundus of the uterus, become spread out over its surface, and ultimately blend with its fibres. Although the fibres of the round ligament are generally said to be of the same kind as those of the uterus, I have not been able to perceive much similarity, either with those of the unimpregnated or the impregnated uterus, the fibres in both these states of the uterus being peculiar. The proper tissue of the unimpregnated uterus is so remarkably dense that there is considerable difficulty in unraveling it sufficiently to display the true character of its fibres, and sections thin enough to admit of being seen as a transparent object by the microscope, give no distinct idea of its real nature. Its characters can be best understood by breaking up portions of the uterus with needles, and examining them in glycerine, but still they should be first seen in water; also the arteries of the uterus should be fully injected (these are remarkably tortuous, and possessed of very thick coats), otherwise the tissue of the small vessels, and the nuclei in the coat of the capillaries, may be examined instead of, and mistaken for, the proper fibre of the uterus. Any part of the unimpregnated uterus, after having been thus treated, will be seen to be made up

* Anatomie Chirurgicale, 1833, vol. ii. p. 372.

† Nouvelles Démonstrations d'Accouchements, p. 62.

of fusiform nucleated fibres, contained in a matrix of exceedingly coherent granular matter; these are well represented in fig. 3. The average breadth of one of these fibres, at its dilated or nucleated part, is about $\frac{1}{4000}$ th of an inch; their length cannot be ascertained with certainty, as it is impossible to estimate the degree of curtailment which they suffer in being separated from the granular matrix in which they lie imbedded. Their structure and size are about the same in every part of the uterus from which I have taken them, so that they are easily recognizable as the peculiar fibres of the unimpregnated uterus. Now comparing these fibres with those forming the walls of the impregnated one, at the full, or at a very advanced period of impregnation, it will be seen that these fibres are become greatly increased in size, deprived of nuclei, and more loosely connected together; they lie in separate planes, which cross each other in various directions; they are accompanied with vessels of various sizes, also with more or less fibro-cellular tissue. The size of these fibres is moderately uniform, but those near to the external surface are rather smaller than those more deeply seated. A fibre detached from the rest measured about $\frac{1}{40}$ th of an inch in length and about $\frac{1}{3000}$ th in breadth at its widest part; for the breadth varies much in different parts of the same fibre, being alternately large and small; at their extremities they taper off to a very fine point; their colour is yellowish, and when minutely examined, they appear to be made up of very small irregular granules and extremely slender threads blended together without any definite arrangement (see fig. 4). Acted upon by acetic acid they give no indication whatever of being nucleated, therefore in this respect they differ from the common form of organic muscular fibre*. The two kinds of fibres, represented in figs. 3 and 4, were both drawn under the same magnifying power, in order to show, by a comparison of their dimensions, that the increase which takes place in the individual fibres in these different states of the uterus, is quite sufficient to account for the amount of augmentation of the entire organ, without supposing, as some physiologists do, that organic muscular fibres, not present in the inactive state of the uterus, are absolutely formed during the various stages of its enlargement; it also, besides being supported by the fact just stated, perfectly accords with the laws of development, and harmonizes with the changes which are going on simultaneously in the walls of the impregnated uterus and its contents; the unimpregnated uterus being, according to this notion, little more than an assemblage of embryonic nucleated fibres, wholly inactive, until after the reception of the ovum, when, being aroused by an appropriate stimulus, they are called into active operation, and become developed simultaneously and proportionally to the development of the foetus contained within it, so that when the one has arrived at a state requiring to be expelled, the other has acquired the utmost degree of fitness necessary to effect its expulsion. Now after the expulsion of the foetus, since, according to the laws of de-

* Professor KÖLLIKER has described the fibres both of the unimpregnated and impregnated uterus. The latter he has described and figured as having nuclei, which I have never been able to verify although I have examined these fibres with the greatest possible care.

velopment, it is as impossible that these fibres of the impregnated uterus can return again to their primitive or embryonic condition, as that a full-formed foetus could relapse into the state of an ovum, they must necessarily become absorbed, and therefore a new set of embryonic fibres would require to be formed for the expulsion of the next ovum, so that each foetus will have, according to this conclusion, its own peculiar expulsive fibres. This view is perfectly in accordance with the late researches of Drs. SHARPEY and WEBER on the membrana decidua; and it agrees with the same function in vegetables, in which the part corresponding to the uterus in animals is always cast off after its contents have been brought to maturity, and separated from the parent plant.

DESCRIPTION OF THE PLATE.

PLATE XXXIX.

- Fig. 1. Represents some muscular fibres taken from the central part of the round ligament of the uterus of the human subject, where it is situated between the layers of the broad ligament.
- Fig. 2. Represents some muscular fibres taken from a part of the round ligament nearer to the uterus than those shown in fig. 1: there the termination of the striated fibres in fasciculi of granular ones is shown.
- Fig. 3. Represents nucleated fibres taken from the unimpregnated human uterus, and the granular matrix in which they are imbedded.
- Fig. 4. Represents fibres taken from the impregnated human uterus at the eighth month of pregnancy.

Fig. 1.

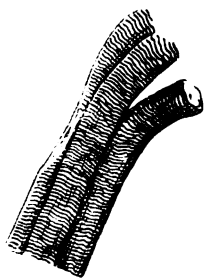


Fig. 2.

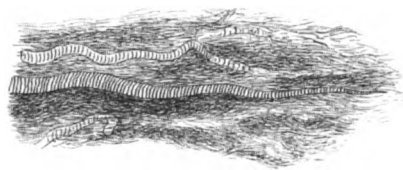
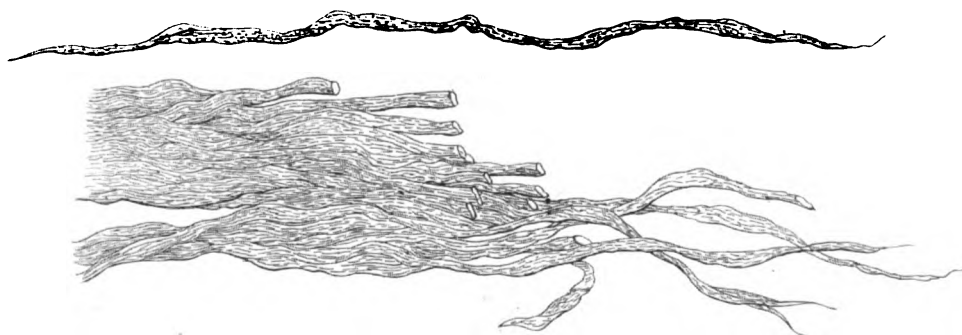


Fig. 3.



Fig. 4.



XXVII. *On the Communications between the Cavity of the Tympanum and the Palate in the Crocodilia (Gavials, Alligators and Crocodiles).*

By Professor OWEN, F.R.S. &c.

Received December 20, 1849,—Read February 28, 1850.

THERE are three perforations which succeed each other along the middle line of the base of the cranium in the Crocodilian Reptiles. The hindmost (Plate XL. fig. 1, *v*), situated in the basioccipital, near the condyle, is the smallest and least constant in size and existence: it gives passage to a vein, which traverses a vertical canal in the bone homotypal with the vertical vascular canal that opens upon the under surface of the bodies of the vertebræ of the trunk. The next foramen in advance, *e*, is larger and on a lower level; it is constantly present and is regular in its size and position: it perforates the fore part of the basioccipital close to the basisphenoid. The third or anterior foramen, *n*, is the largest, and opens on a still lower plane: it is formed entirely by the pterygoids, which it perforates in a forward direction, and is the posterior aperture of the nasal passages.

There exists a difference of opinion as to the nature of these latter foramina, and especially as to the function of the middle foramen, *e*, viz. that which perforates the basioccipital close to the basisphenoid. CUVIER describes it in his celebrated chapter on the Osteology of the Crocodile, in the last volume of the 'Ossemens Fossiles,' p. 78, 4to, 1824, as leading to "a canal which traverses the body of the sphenoid, and terminates by two branches opening into the 'sella turcica,' and, at p. 133, he refers to it in the cranium of the 'Gavial de Caen' (*Teleosaurus cadonensis*, GEOFFROY), as an arterial foramen ('le trou des artères')." The continuators of CUVIER, in the posthumous edition of the 'Leçons d'Anatomie Comparée,' t. ii. p. 523, describe the foramen in question more accurately, as leading to a canal which bifurcates as it ascends; one of the branches traversing obliquely the body of the sphenoid, whilst the other perforates the basilar part of the occipital, and opens into the cavity of the internal ear. They do not state where the branch terminates which traverses the basisphenoid*, nor what passes through either canal.

In the description of the tympanic cavity of the Crocodile†, no mention is made of this communication, or of the Eustachian tube, which is described in the Saurians

* I use here, and throughout this paper, the English equivalents of the French phrases defining the bones of the Crocodile's skull, according to the table of synonyms, No. 1, in my work 'On the Archetype of the Vertebrate Skelton,' 8vo, 1848.

† *Op. cit.*, tom. iii. p. 512.

generally as communicating with the palate by a wide and short canal (p. 511). But in a supplementary paragraph to CUVIER's description of the foramina in the base of the skull of the Crocodile, the osseous aperture of the Eustachian tube is stated to be perforated in the exoccipital, near its junction with the basioccipital, and to be situated below the anterior condyloid foramen*.

In the 'Report on British Fossil Reptiles,' communicated to the British Association in 1841†, I described the foramen in the basioccipital, *e*, as the common terminal canal of the Eustachian tubes, and the foramen in advance of it, *n*, as the posterior aperture of the nasal canals.

In the 'Abhandlungen über die Gavial-artigen Reptilien des lias-formation,' fol. 1841, by Professors BRONN and KAUP, it is argued at great length (pp. 12, 16, 24) that the median foramen, *e*, is the true posterior aperture of the nostrils; and a letter from Professor DE BLAINVILLE, dated December 8th, 1841, is cited by those authors in support of their view, in which letter CUVIER's determination, that it was 'an arterial foramen,' is rejected, and Professor BRONN's opinion is stated to be completely confirmed by the appearances in the original fossil skull of the *Teleosaurus* from Caen, described and figured by CUVIER.

Besides the median foramina above specified, there are several lateral foramina, in symmetrical pairs, in the same part of the base of the skull of the Crocodile. One on each side the base of the condyle, Plate XL. fig. 1, *p*, is the 'precondyloid foramen,' which gives exit to the hypoglossal nerve: external to this is a larger foramen, *t*, through which pass the eighth pair of nerves and a vein from the tympanic cavity; below these, and still in the exoccipital (2), is the foramen, *c*, described by the continuators of CUVIER as the bony outlet of the Eustachian canal; and still lower down, in the suture between the basioccipital (1) and basiphenoid (5), is the foramen, *el*, which I have not found noticed by any anatomical author.

The decisive test of the nature of these latter foramina, *el*, and of the different opinions respecting the foramina, *c*, *c*, and the median foramina, *e* and *n*, was, of course, to be sought for in the results of an accurate anatomical examination of the parts in the recent Crocodile. I have, accordingly, availed myself of the opportunities liberally afforded to me by the Council of the Zoological Society, to dissect for this purpose specimens of an Alligator (*Alligator lucius*) and a Crocodile (*Crocodilus acutus*) which have died at the Zoological Gardens; the examination being made after injecting the vessels of the head with coloured wax.

The entocarotid arteries (Plate XL. fig. 2, *c*) enter the foramina (fig. 1 *c*, *c*) situated, one in each exoccipital bone, 2, at the side of the base of the condyle, below

* "Le trou condyloïdien est dans l'occipital latéral, et en dehors de lui est un trou assez grand pour des vaisseaux. L'ouverture osseuse de la trompe d'Eustache est au dessous des précédents, aussi dans l'occipital latéral, et tout près du point de réunion de cet os avec le basilaire et le sphénoïde."—Leçons d'Anat. Comp. tom. ii. p. 524, 1837.

† Reports, 8vo, p. 96.

the outlet for the hypoglossal and eighth pair of nerves, *t* and *p*. In a young Crocodile, with a head of eleven inches in length, the common trunk, fig. 2, *cc*, of both carotids is continued along the under surface of the cervical vertebræ as far as the dentata, where it bifurcates into the two carotids: these diverge, ascend, inosculate with the vertebral artery, *v*, and subdivide into the ectocarotid, *ec*, and entocarotid. The latter artery, *c*, at the first part of its course, extends obliquely forwards inwards and upwards, protected by a bony canal, half an inch in length, which terminates by projecting freely as a tube of a line in length (Plate XLI. fig. 4, *c*), opening into the cavity of the tympanum beneath the bony plate, 16, to which I have restricted the term 'petrosal*.' The artery emerging from the bony canal extends forward across the base of the tympanic cavity, covered only by a reflexion of its lining membrane, for about a third of an inch, and then enters a second bony canal, opening into the fore part of the tympanum, and continued to the 'sella turcica,' where the carotid enters the cranial cavity, as is shown in Plate XL. fig. 3, *c*.

No artery enters the single median foramen, Plate XL. fig. 1, *e*, situated close to the suture between the basioccipital and basisphenoid. The soft palate which covers this part, immediately behind the true posterior nares, forms a subcircular protuberance with a single central aperture (Plate XLI. fig. 5); this aperture is also partly closed by a valvular membranous prominence, *x*, which reduces its area to a crescentic form. This orifice in the soft palate is not, as I had supposed, continued exclusively from the bony orifice in question, *e*, immediately above it; but is the common palatal outlet of three canals, one of which, *e*, is median, extending into the bony canal, figs. 6 and 7, *e*, which ascends into the substance of the basisphenoid; the other two, *el*, are membranous for the extent of eight lines, and diverge as they ascend to penetrate the fissures, fig. 7, *el*, one on each side of the larger median foramen, and which lead to canals, fig. 7, *el'*, extending upwards between the basioccipital and basisphenoid.

From the inferior openings, Plate XL. fig. 1, *el*, of these canals in the dry skull, grooves lodging their membranous prolongations are continued to the common median fossa into which the middle osseous canal, fig. 7, *e'*, opens by the foramen, *e*, in question. Dissections of the recent parts demonstrated that this foramen, like the two lateral canals, communicated by a membranous tube (fig. 5, *e*) with the surface of the palate and would receive air from the mouth. It was next to be determined where the air would be conducted by those tubes; and the passage leading from the median foramen was first traced. In an alligator with a head 14 inches in length, the foramen, *e*, leads to a canal lined by a continuation of the palatal membrane, which ascends along the suture between the basioccipital and basisphenoid, for nearly 2 inches, and then bifurcates; one branch inclining forward into the basisphenoid, the other rising vertically into the basioccipital, and both in the same

* It was probably the observation of this structure in the dry skull that misled the continuators of CUVIER into the belief that the canal, *c*, was the osseous part of the Eustachian tube.

median plane. I followed out the further course of these canals in the skull of a *Crocodilus acutus* of about the same size as the recent Alligator. Figure 7, Plate XLI. shows the common median canal extending from *e* to *e'*, where it divides. Each of these branches subdivides, and sends its subdivisions, one to the right the other to the left, to communicate with the tympanic cavity. The lateral canals, *el'*, which commence below at *el*, one on each side of the median foramen, communicate with the lateral subdivisions, *eo*, of the posterior or basioccipital branch of the common median canal; a small rhomboidal sinus, *eo'*, being formed at their point of union, from which a short canal is continued to the tympanic cavity. Thus each lateral canal, *el'*, with each posterior lateral subdivision, *eo*, of the basioccipital branch of the median canal, has a common opening into the base of the tympanic cavity of its own side. Each lateral subdivision, *es*, fig. 8, Plate XLII., of the anterior or basisphenoid branch of the median canal opens into the tympanic cavity at *es*, fig. 10, in advance of the preceding orifice. The lining membrane of these several canals here becomes continuous with that of the tympanic cavity.

Thus it was seen that no passage from the median orifice or canal in question, *e*, figs. 1 and 7, between the basioccipital and basisphenoid, conducted to the nasal passages, but that all the branches from that common orifice opened into the tympanic cavity: at the same time it was demonstrated, that the communication between the tympanum and the palate, commonly called the 'Eustachian tube,' was more complex in the Alligator and Crocodile than had been suspected, or than was known to exist in any other animal. It may be described as follows:—From each tympanic cavity two passages are continued downward, one from the fore part, Plate XLII. fig. 10, *es*, the other from the floor, *ib. eo*, of the cavity. The anterior canal, *es*, passes downwards and inwards, expands and again contracts before it unites with its fellow from the opposite side at *es'*, fig. 8, to form a median canal, *es'* to *e'*, which passes from the basisphenoid to the space or broad suture between that bone and the basioccipital, where it terminates in the single subvertical canal, *e'* to *e*, descending along that suture to the median foramen in question, *e*, fig. 1.

The opening at the floor of the tympanic cavity, *eo*, fig. 10, leads to a short canal, *eo*, figs. 7 and 8, which curves towards its fellow from the opposite tympanum, but first swells into the rhomboid sinus, fig. 7, *eo'*, and divides; one branch descends almost vertically, *el'*, and terminates by the small foramen, *el*, fig. 1, in the osseous groove or channel leading to the central aperture and fossa; the other branch, *eo* to *eo'*, fig. 8, continues the course inwards and downwards until it meets its fellow at the median line of the basioccipital at *eo'*, and forms the posterior primary division of the common median canal, *eo* to *e*: this soon joins the anterior division, at *e'*, to form that common canal, which then descends and terminates by slightly expanding into the foramen, *e*, at the middle of the fossa between the basioccipital and basisphenoid; which fossa receives also the grooves lodging the membranous canals from the lateral fissures. Finally, the three bony canals terminate by their membranous continuations

e and *el*, fig. 5, Plate XLI., in the single Eustachian valvular outlet, *x*, on the soft prominence behind the posterior nares, *n*.

The canals from the lateral orifices, *el*, are partially divided by a longitudinal ridge of bone projecting into them from their anterior wall : and the dilated lateral branches of the alisphenoid division of the median canal, *es*, are impressed by a longitudinal groove. I may also remark, that at the upper part of their place of confluence or termination, there is a median fossa leading to a small vascular canal.

The tympanum of the Crocodiles, Plate XLII. fig. 10, is very extensive, by reason of the air-cells continued from it, not only into the mastoid, but across the basi-occipital and basisphenoid*, and into the exoccipital, supraoccipital†, alisphenoid and parietal bones‡.

By the dissection of a young Gavial of the Ganges, preserved in spirits, and a comparison of this with sections of the cranium of a full-grown specimen, I have satisfied myself that the third median system of Eustachian tubes, as well as the two lateral tubes, exist in the Gavials as in the Alligators and true Crocodiles; only in the Gavial the common terminal canal of the median system is shorter, as is shown in Plate XLII. fig. 9, *e*, *es*, *eo*.

It appears to have been still shorter in the extinct *Teleosauri*; the posterior primary division of the canal which penetrates the basioccipital forms, in the section of the skull of the Caen Teleosaur, a subcircular depression, which is filled with the matrix in the Parisian specimen. The anterior primary division, answering to *es*, fig. 9, plainly perforates the substance of the basisphenoid, as it ascends obliquely forwards, and therefore can by no means be regarded as the posterior termination of the nasal passages, which, in the *Teleosauri*, are surrounded exclusively by the pterygoids, as in all the existing forms of *Crocodylia*.

With regard to the homologies of the above described complex Eustachian or palato-tympanic air-passages in the *Crocodylia*, the lateral bony canals, *el*, fig. 7, terminating at the grooves, *el*, answer to the simple Eustachian tubes of lizards and mammals: the median canal, *e*, *e'*, with its dichotomous divisions, is a speciality peculiar to the *Crocodylia*.

I forbear, with my present limited experience of the living habits and actions of the Crocodilian Reptiles, to offer any hypothesis as to the function of the complex canals which conduct the air and would convey its sonorous vibrations from the nose to the ear: but one peculiarity I may suggest, as being probably related to the structures in question, in which the Crocodiles and Gavials differ from all the Lizard-tribe, viz. that of habitually floating with the operculated meatus externus submerged, and only the eyes and the prominent nostril exposed above the surface of the water. Any noise in the air that might reach the floating reptile would, under such conditions, be conveyed to the tympanum by the canals conducting to that cavity from near the

* On the Archetype of the Vertebrate Skeleton. 8vo. VAN VOORST, fig. 9, p. 22, 1 and 5.

† *Ibid.* 3.

‡ *Ibid.* fig. 19, p. 120, 6 and 7.

hinder opening of the long nasal passage; and it may also be remembered, that there is a peculiar valve in the Crocodiles which shuts off all communication between that passage and the mouth.

DESCRIPTION OF THE PLATES.

PLATE XL.

Fig. 1. A view of the hinder part of the base of the skull of a Crocodile, showing :—

- .*v.* The venous foramen.
- e.* The median Eustachian foramen.
- el.* The lateral Eustachian foramina (the canal, *el'*, is laid open on the right side).
- n.* The posterior nasal aperture.
- c.* The carotid foramina.
- p.* The precondyloid nervous foramina.
- t.* The foramen jugulare.
- 1. The basioccipital.
- 2. The exoccipital.
- 5. The basisphenoid.
- 24. The pterygoid. The bristle ending at this figure is passed through the median canal and right subdivision of its basioccipital branch through the sinus of communication with the lateral canal, which is laid open between *t* and *c*.

Fig. 2. A view of an injected preparation of the *Crocodilus acutus*, showing the course of the carotids *cc*, vertebral artery *v*, and entocarotid *c*, to its foramen, and through the posterior bony canal into the tympanic cavity.

Fig. 3. Showing the emergence of the entocarotids, *c*, from their anterior bony canals opening into the sella turcica, their sinuous course forwards, and confluence into the single artery continued into the rhinencephalic division of the cranium.

PLATE XLI.

Fig. 4. A section of the skull of a *Crocodilus biporcatus*, showing the free or prominent tubular termination of the posterior bony carotid canal in the tympanic cavity; *c*, a style passed through the canal; 16, the petrosal.

Fig. 5. A section of the bony and soft parts of the palate of an Alligator (*All. lucius*), showing the posterior nares, *n*, the common median valvular aperture, *x*, of the median, *e*, and the two lateral, *el*, Eustachian canals; bristles are passed along the membranous portions of these tubes.

Crocodilus acutus

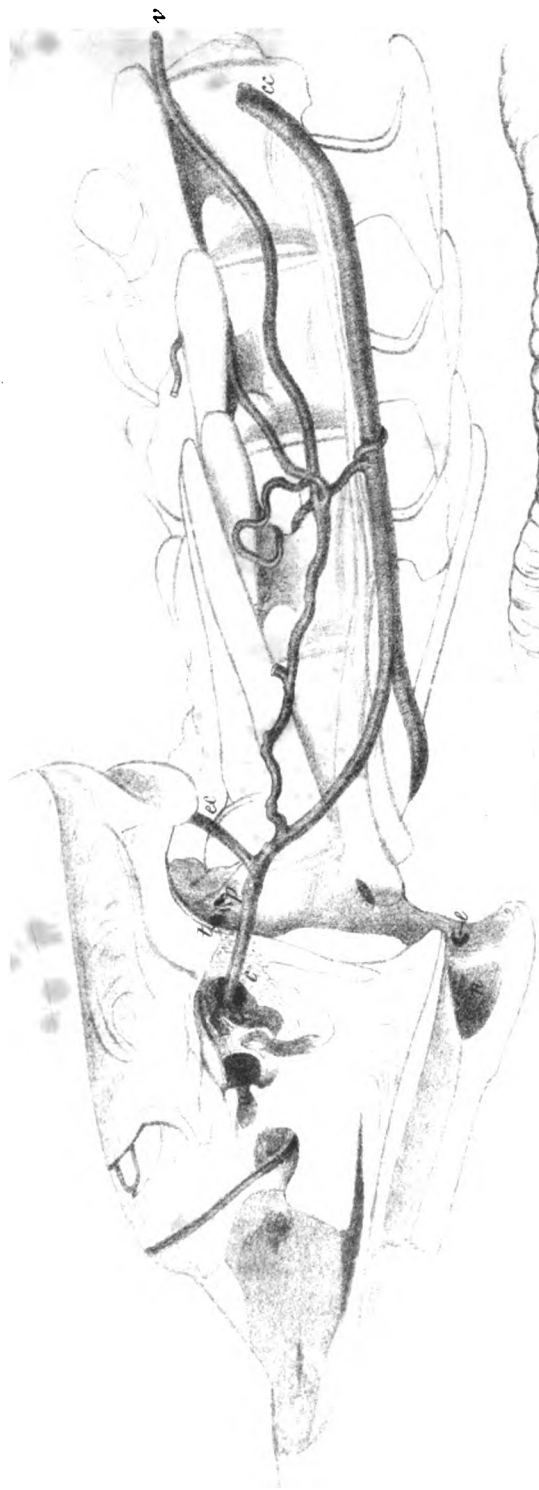


Fig 2.

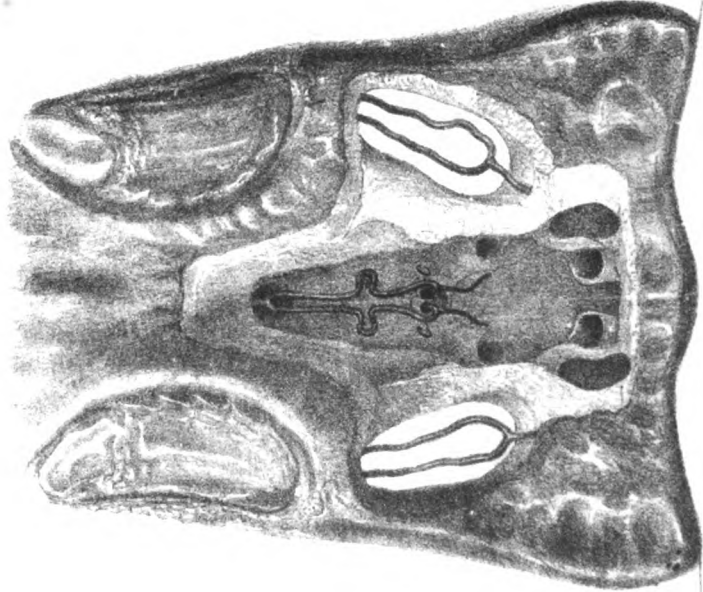


Fig 3

Crocodilus acutus



Fig 1.

Crocodilus biporcatus

Printed by J. Baskin.

65. Crocodilus biporcatus

Fig. 5.

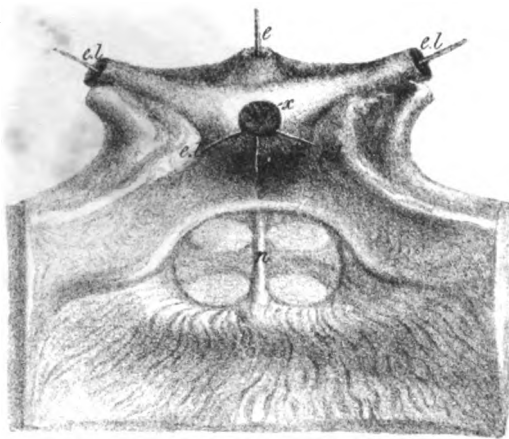
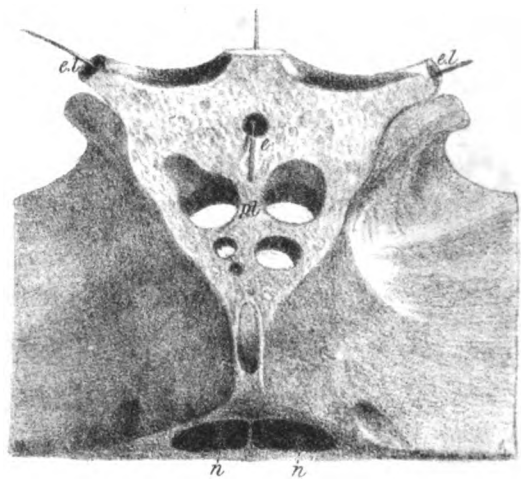


Fig 6



Alligator lucius

Fig 7.

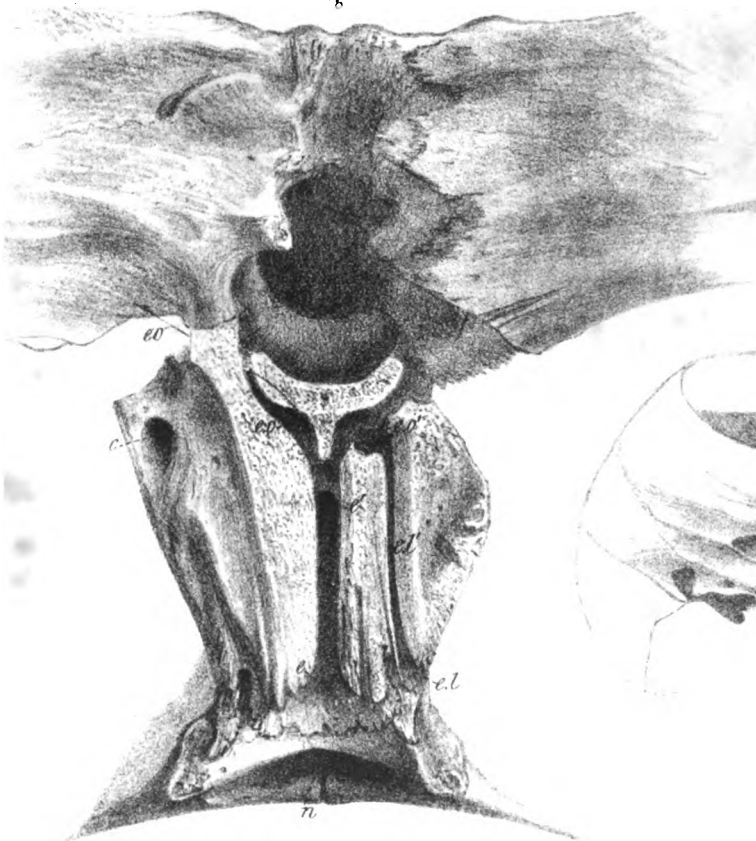
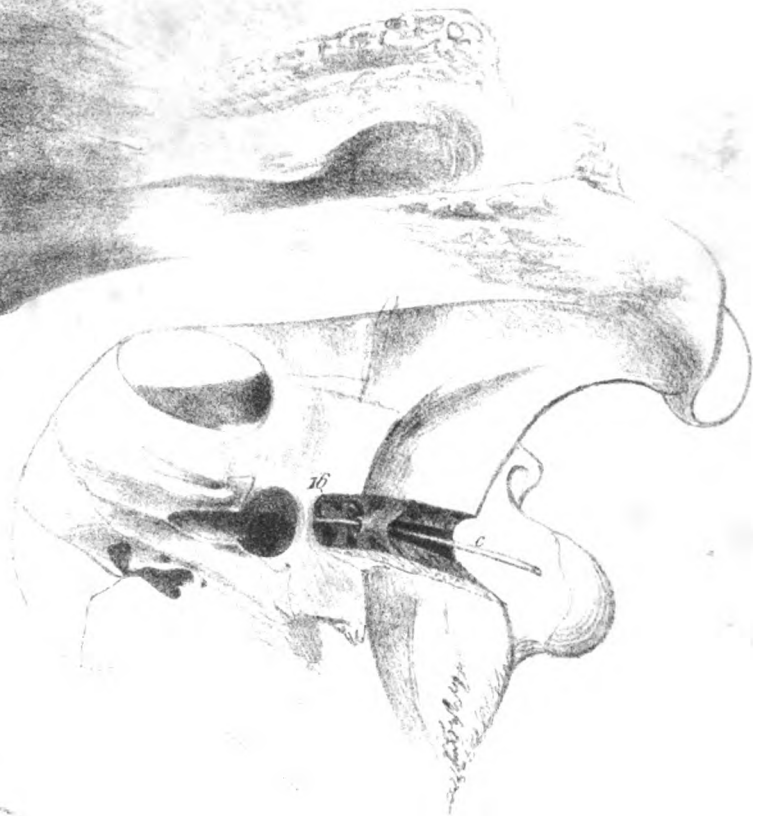


Fig 4.



Crocodilus acutus

Crocodilus biporcatus

Fig. 8.



Crocodilus biporcatus.

Fig. 10.

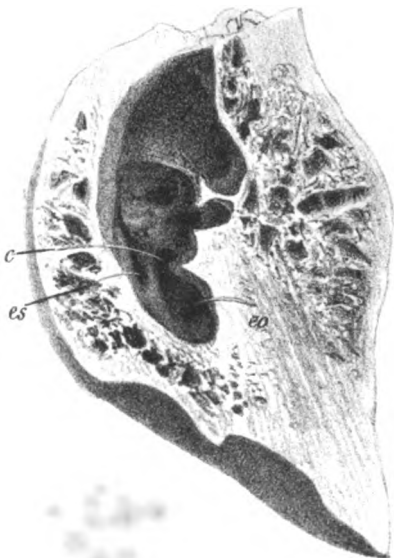
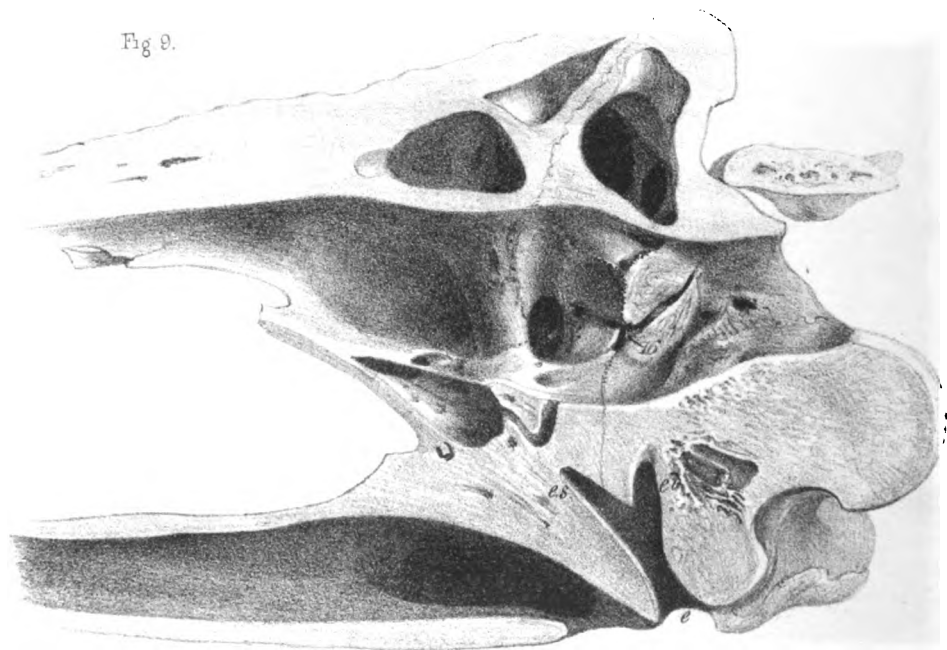


Fig. 9.



Gairalis gangeticus

Fig. 6. The opposite side of the same section, showing the median bony Eustachian canal, *e*, the lateral membranous Eustachian canals, *el*, cut off where they join the lateral bony canals, and the pterygoid air-cells, *pt*, communicating with the posterior nares, *n, n*.

Fig. 7. A section of the cranium of the *Crocodilus acutus*, showing the course of the median Eustachian canal, *e*, to its bifurcation at *e'*, the division of the basioccipital branch, *e'* to *eo*; the course of the left lateral Eustachian canal, *el'*, to its communication, at the rhomboidal sinus, *eo'*, with the tympanic branch of the basioccipital division of the median Eustachian canal.

PLATE XLII.

Fig. 8. A vertical section of the cranium of the *Crocodilus biporcatus*, a little to the left of the median line, showing part of the left tympanic branches, *es, eo*, and the orifices, *es', eo'*, of the right tympanic branches, of the primary divisions of the median canal, *e'* to *e*.

Fig. 9. A vertical median section of the cranium of a Gavial, *Gavialis gangeticus*, showing the basioccipital division, *eo*, and the basisphenoid division, *es*, of the median Eustachian canal, *e*.

Fig. 10. A vertical section of the tympanic cavity of the *Crocodilus biporcatus*, showing bristles inserted into the basioccipital branch, *eo*, and basisphenoid branch, *es*, of the Eustachian tube; *c*, the entry of the entocarotid canal.

XXVIII. *On the Structure of the Dental Tissues of the Order Rodentia.**By JOHN TOMES, Surgeon-Dentist to the Middlesex Hospital.**Communicated by WILLIAM BOWMAN, Esq., F.R.S.*

Received February 19,—Read May 30, 1850.

IN a memoir on the Structure of the Dental Tissues of Marsupial Animals, printed in the second Part of the Philosophical Transactions for 1849, I pointed out certain peculiarities in the structure of the enamel common, with one known exception only, throughout that order of quadrupeds, and found in other mammalian teeth in a few isolated cases only*.

* Having in a former paper† stated that the continuation of the dentinal tubes into the enamel appears to be a constant character in the teeth of marsupial animals, excepting only in those of the Wombat, I can now add that I have found it to hold good in many other members of the families from which I have already given examples; and also in members of those families which are not mentioned in my paper; and moreover, that further research has exposed no other exception to the rule than that which I have already cited.

I find that in *Macropus penicillatus* most, if not all, of the coronal dentinal tubes are continued into the enamel, and in the latter part of their course are bent rectangularly downwards towards the fang of the tooth. In *Halmaturus Derbianus* the dentinal tubes are continued into the enamel, but are not subject to the terminal flexure observed in the preceding example. The dental tissues of the *Dasyurus viverrinus* closely resemble those of the *Dasyuri* already described. The teeth of *Didelphis californica* and *Didelphis cancrivora*, approach very closely in structure to those of the *Didelphis virginiana*.

I am indebted to Mr. GOULD for opportunities of examining the teeth of *Myrmecobius fasciatus*, *Perameles nasuta* and *Chacropus*. In each of these creatures the dentinal tubes are continued into the enamel. In *Phascolarctos fuscus*, the dentinal tubes that proceed towards the tubercles of the teeth are continued in considerable numbers into the enamel; but on the sides of the teeth their continuation is less frequent. Here the enamel fibres are more strongly marked, and larger than in any other marsupial tooth that I have examined.

Several specimens of fossil marsupial teeth have been examined, and are found to correspond in structure with those of the recent species, to which the fossil ones are most nearly related.

November 24, 1849.

† Philosophical Transactions, Part II. for 1849.

It is the purpose of the present communication to lay before the Society results obtained from an examination of the teeth of various members of the order Rodentia. I have had the opportunities necessary for extended researches in this division of Odontography, partly through the assistance of numerous friends, but principally through the liberality of the Council of the Zoological Society, who granted me the privilege of examining teeth from the duplicate specimens of their large collection of skulls. At the time I commenced the investigation, there seemed but little hope of finding any strongly marked and characteristic differences of structure in the dental tissues of the several families of this order of quadrupeds. The teeth of many rodents had already been submitted to the microscope, and the results published*. I had not proceeded far, however, in the investigation of this highly interesting subject, before it became apparent to me that the family Hystricidæ and the Sect. Bathyergina of WATERHOUSE have a constant and exclusive character in the structure of the enamel; that the Sciuridæ have another character; that the first and second sections of the family Muridæ possess a third; and that the remaining sections of that family possess a fourth well-marked character, and the Leporidæ a fifth. I am told by Mr. WATERHOUSE that these results are of great importance, as affording evidence on the position of several species whose place in the order has not been definitely fixed, either by their external characters or by the structure of the skull, and hence they have been variously placed by naturalists, and even by the same author at different times.

Before entering on a description of the structural characters that pertain to the teeth of the rodential families, or of individual teeth, it will be desirable to state those conditions which are common to the whole order, otherwise it would be necessary to repeat frequently the same fact. It has long been known that the incisors of Rodentia have the property of unlimited growth, and that the rate of growth equals the rate of loss by wear; hence the exposed portion of the tooth is, in the normal state of the dental apparatus, maintained of uniform length. The pulp-cavity in a longitudinal section of the tooth is irregularly conical or wedge-shaped, and in a transverse section corresponds in some measure with the outline of the tooth. The dentinal tubes pass from every part of the cavity outwards and upwards towards the surface in more or less curved lines.

The tubes which proceed from the cavity near the base of the tooth, are in many cases perceptibly larger than those that are situated higher up; hence it follows, that, as the latter were once near the base of the tooth, the dentinal tubes undergo a diminution of calibre after their formation. In the teeth of the Sciuridæ, I have found a difference of size amounting to a third or half between the tubes near the base and those near the surface, in wear. Professor OWEN has observed that the tubes in the posterior or lingual half give off larger and more numerous branches than those constituting the anterior half of the tooth. My own observations lead to the conclusion, that this difference does not always exist near the surface of the pulp-cavity,

* Odontography, Prof. ERDL.

but is generally present towards the outer surface of the tooth. The tubes in the anterior half gradually diminish in calibre from their commencement, while those in the posterior half retain their dimensions until they arrive near the surface, where they break up into branches.

At and near the apex of the pulp-cavity the development of dentinal tubes is suspended. The tooth at this point is rendered solid by the conversion of the pulp into a clear laminated subgranular mass, into which very few, if any tubes are continued; and the few that are sometimes found are usually small in size, irregular in form and direction, and never reach the centre. The ends of the dentinal tubes are perfectly sealed up, and their connection with the pulp-cavity and its vascular contents completely cut off in the manner shown in Plate XLIII. fig. 1. The perfected part of the tooth is rendered by this process in the fullest sense of the word extra-vascular. A similar condition may be seen in the molars of persistent growth, and offers a striking difference to the condition of the rooted teeth, in which the dentinal tubes retain their connection with the pulp-cavity until the tooth becomes diseased or dead, or the crown worn down by mastication. In the latter case, as the crown wears down, the pulp is converted into secondary dentine, in which but few tubes exist, and these do not reach a vascular surface like that which lies in contact with the surface of the pulp-cavity in the normal state of the tooth.

Professor OWEN*, after describing the manner in which the incisor teeth of rodents are developed, says, "The tooth thence projecting consists of a body of compact dentine, sometimes with a few short medullary canals continued into it from the persistent pulp-cavity, with a plate of enamel laid on its anterior surface, and a general investment of cement, which is very thin upon the enamel, but less thin, in some rodents, upon the posterior and lateral parts of the incisor."

The medullary canals described by Professor OWEN, pursue a course parallel with the dentinal tubes, form a narrow loop, and return to the pulp-cavity. The dentinal tubes never radiate from them, but enter through the medium of lateral branches only (fig. 5). Hence the teeth so constituted do not form an exception to the law, that the incisors of rodents are formed of a single denticle†, which, exclusive of the enamel, is comparable to an Haversian system.

* Odontography, page 399.

† It is proposed to restrict the term *dentinal system* to a canal from which dentinal tubes radiate (fig. 2), and *denticle* to a dentinal system coated with enamel or cementum; and that a tooth composed of a series of dentinal systems, each coated with enamel and united into one tooth by cementum, shall be described as a tooth composed of denticles. The molars of the *Capybara* afford an excellent example of a tooth constituted in the latter manner, while the *Orycteropus* affords an equally good example of a tooth compounded of a series of dentinal systems—a tooth in which we have a number of medullary canals from which dentinal tubes radiate, the terminal branches of which inosculate with the terminal branches from neighbouring systems, either by confluence or the intervention of small cells (fig. 2). Teeth composed of a series of dentinal systems may or may not have an external investment of enamel; in the *Orycteropus* enamel is absent, while in the *Labyrinthodon*, *Varanus* and *Lepidosteus*, it is present near the upper extremity of the tooth. The dentinal systems commonly run into each other at some

In those rodents whose molars are of persistent growth, whether the tooth is composed of denticles or confluent denticles, the dentinal tubes of that part of the tooth which is protruded and exposed to wear, are cut off from their connection with the pulp-cavity in the same manner as in the incisors. This beautiful provision of nature for rendering solid and extra-vascular parts that are about to be exposed to mechanical abrasion from external objects, is not confined to the teeth of rodents, or to dental tissues alone.

The *Orycteropus* has teeth which are permeated by a series of canals, which take a parallel course at tolerably regular intervals in the length of the tooth. From each canal a system of dentinal tubes radiates, the terminal branches of which inosculate with corresponding ones from neighbouring systems. In the protruded portion of the tooth, the medullary canals are rendered solid by the development of a clear non-tubular tissue, whereby the once open extremities of the tubes are closed (fig. 2).

The teeth of reptiles of the genus *Varanus* are at their middle part and base composed of a series of dentinal systems, as are those of the *Labyrinthodon** (fig. 3). In

parts, in the same manner as the Haversian systems do in bone. But there are many instances in which parallel dentinal systems are united to each other, throughout their whole length, by a thin longitudinal lamina of dentine, the tubes of which belong as much to the one as to the other system, while the free parts of each system are coated with enamel, and this with cement. The molar teeth of the Water-Rat and *Ondatra* offer good examples. It is desirable to have a term to express this condition; *confluent denticles* would, I think, answer the purpose, and *confluent dentinal systems* where a like condition is observed, without the presence of enamel or cementum as a uniting medium.

* It has been usual to describe the tooth of the *Labyrinthodon* as being divided into numerous compartments, by tortuous inflections of the cementum from the surface towards the centre. I believe it is admitted by writers on Odontography, that when enamel and cementum are present in the same tooth, the latter tissue holds a position external to the enamel. Professor OWEN, in his paper on the teeth of the *Labyrinthodon*, printed in the Geological Transactions, says of the *Ichthyosaurus*, "In this extinct Saurian the external layer of cement (for the enamel ceases at the base of the crown) is inflected at pretty regular distances around the circumference of the tooth towards its centre:" then again, "The plan and principle of the structure of the tooth of the *Labyrinthodon* are the same as those of the tooth of the *Ichthyosaurus*, but are carried out to the highest degree of complication." But in a beautiful series of sections of the tooth of the *Labyrinthodon Jaegeri* in the possession of Dr. MANTELL (to whom I am indebted for their use), it is clearly shown that the division of the tooth into numerous compartments takes place within a general investment of enamel, external to which the cementum would be placed if it existed on this part of the tooth.

The inflections of the cementum, observed by Professor OWEN in the tooth of the *Ichthyosaurus*, and compared by him to the supposed inflection in the tooth of the *Labyrinthodon*, take place, as he observes, below the terminal line of the enamel; hence the two cases do not admit of comparison. Similar cells to those which occupy the line which lie between the dentinal system and serve as a medium of connection between the dentinal tubes of adjoining systems in the latter animal, are found in equal or even greater numbers near the periphery of the dentine, and within the enamel of very many teeth. Hence the presence of these cells in the tooth of the *Labyrinthodon* is not sufficient to prove the existence of cement between the dentinal systems, unless it is at the same time shown that they are external to the enamel, or that that tissue is absent. The tooth of the *Labyrinthodon* is in truth made up at its apex of a single dentinal system coated with enamel; below, it is divided into numerous systems, which have a peculiar and characteristic outline and position. Each system usually coalesces at one part of its circumference with a neighbouring system, by a narrow vertical process of

fish we have the teeth of the *Dendrodus*, the *Lepidosteus*, *Myliobates*, and sharks of the genus *Lamna*, also composed of a series of dentinal systems. In all of these the open extremities of the dentinal tubes are closed previous to the part being exposed by wear. A similar condition, in a beautiful state of preservation, is found in many fossil fish teeth, especially in the *Cestracions*. I cannot refrain from noticing one other instance of this condition. The antlers of the Stag are composed of Haversian systems of medullary or vascular canals, surrounded by concentric laminæ of osseous tissue interspersed with lacunæ, the canaliculi of which anastomose freely, and those situated near a vascular canal terminate by open mouths on its surface. Previous to the shedding of the antler, each of the larger canals becomes lined with a layer of transparent, dense and almost structureless tissue, which completely closes the mouths of the canaliculi and cuts off the connection of the elaborate system of tubes and lacunæ with the vascular canals (fig. 4).

The division of the enamel of the incisors into two layers, described by Professor OWEN, I have found common throughout the order, excepting in the incisors of the Hares and the Rabbit: the *Lagomys* I have not had an opportunity of examining, but from their close relation to the Hares, it is more than probable that in their incisors the enamel is not divided into an outer and inner layer.

The term layer is open to objection, as the two parts are made up of continuous fibres. In the inner part they decussate, while in the outer they are parallel, but their continuity may be distinctly traced (fig. 6 to 50). In the molars of many *Hystricine* teeth, the usual order is reversed; in the inner portion the fibres are parallel, and in the outer part of the enamel they decussate.

Professor OWEN, in the passage cited, and in other parts of his great and valuable work, states that the cementum is continued over the enamel in the incisors of rodents, and objects to some of Professor ERDL's figures printed in his work on the Microscopic Structure of the Molars of *Rodentia*, because this tissue is left out. He says Professor RETZIUS failed to recognize the cementum from its being coloured. Professor OWEN*, in his description of the incisor of the Water Vole, says, "The layer of cement becomes thinner at the margin of the enamel, where it is continued from the dentine upon that part, but soon increases in thickness, acquiring the bright brown tint, and separated by a well-defined line from the outer clear layer of the enamel."

* I have sought with care for cementum on the anterior surface of the incisors of the Water Vole, of which the foregoing quotation is a description, and also in numberless other teeth, but have failed to find that tissue. In most, if not in all incisors of rodents, cementum may be seen investing the posterior surface, and it may be traced

dentine, much in the same manner as the confluent denticles of the molar teeth of *Rodentia* are united. In the teeth of the *Lepidosteus* and Lizards of the genus *Varanus*, the dentine of the middle and basal portions is divided into systems somewhat in the same manner as in the *Labyrinthodon*, and in the upper part of the tooth within a general circumferential investment of enamel. I have in my possession sections from two species of *Varanus*, *V. Bellii* and *V. Niloticus*, in which this point is incontrovertibly shown. I am indebted to the kindness of Dr. ANDREW SMITH for the teeth of these species.

* Odontography, page 405.

on to the edge of the enamel, where it speedily thins and is lost. The bright brown coloured part is very distinct in many teeth, and when the section is thick and a little oblique looks like a distinct layer; but if the section be reduced in thickness, all appearance of a layer will be lost. The colour graduates insensibly into the enamel, and no defined line of separation between the coloured and colourless parts can be distinguished. The colour has the aspect of a stain, deepest at the surface, and fading as it proceeds inwards. In a favourable section, the enamel fibres may be traced through the coloured part to the surface of the tooth, as shown in many of the figures. In the molar teeth of continuous growth, the cement may be traced over the whole surface of the enamel, and as a thin transparent layer devoid of lacunæ. In these teeth it is however separated from the enamel by a sharply-marked boundary line. In no instance have I found it graduated into the latter tissue in the manner Professor OWEN supposes it to be in the coloured external portion of the enamel of the incisors. In the incisors of the Wombat, the cementum is continued over the enamel, but the two tissues are separated from each other by a sharply-marked line. The cementum is nowhere graduated into, or "blended with*" the enamel. It is more than probable that the thin transparent and almost structureless basement tissue of the enamel-pulp becomes calcified with the attached columns of the pulp itself, but this tissue is quite distinct from the cementum matrix, and exists in those teeth in which we have an external investment of cement.

The rootless molars of rodents have generally a very close resemblance in structure to the incisors, especially in the structure of the enamel. But the rooted molars are less like the front teeth, and in many instances cannot be distinguished by their structure from other small teeth. In the Rat-tribe, however, the enamel near its terminal edge assumes an arrangement similar to that of the incisors. In those molars which have an intermediate character, the structure of the enamel in the upper part of the tooth resembles that of the rootless molars†.

* Odontography, page 405.

† In describing individual teeth, it will be necessary to repeat frequently the same expression, I will therefore state once for all the meaning I attach to such terms. Thus by a vertical or longitudinal section of an incisor, I mean a section from back to front through the median line of the long axis of the tooth; by an oblique section through the long axis of the tooth or oblique longitudinal section, I mean that the section should pass from the mesian side of the anterior to the outer side of the posterior surface of the tooth, or *vice versa*; by longitudinal section from the anterior surface, I mean a section by which a portion of the anterior convex surface is removed with a portion of enamel at each end of the section; by a transverse section, a section at a right angle with the long axis of the tooth; by an *oblique transverse section*, or a section parallel with the surface in wear, a section crossing the long axis of the tooth obliquely from back to front. The surface in wear will be described as the upper surface, both in upper and lower teeth; and the angle at which the enamel layer leaves the dentine, will be that formed between the enamel lamellæ and the surfaces of the dentine immediately above them.

When the thickness of the enamel and the dentine is given, the measurements will be taken from back to front, through the centre of the long axis of a transverse section.

Teeth obtained from the Zoological Society are indicated by the Society's name being affixed to the name of the species.

In the genera *Sciurus* and *Pteromys*, I have examined the dental tissues of many species, and find the teeth so like the one to the other, that the microscope affords no aid in the distinction of species. Under these circumstances it will be necessary to describe minutely the structure of the component tissues of the teeth of one species only.

Sciurus niger, LINN. (Zoological Society).—The anterior surface of the incisors is coated with an extremely thin layer of enamel, scarcely exceeding in thickness the 428th part of an inch. The dentine measured from the front to the back, is about the 8th part of an inch in thickness. A longitudinal section, taken from the centre of an upper incisor, exhibits the dentinal tubes in their length. Those destined for the anterior half commence at the surface of the pulp-cavity, and proceed with slight secondary undulations, and a decreasing calibre upwards towards the enamel. In the earlier part of their course, a few short, minute, rectangular branches are given off, and are soon lost; but when nearing the enamel, the tubes break up into a lash of branches, which pass onwards with but slight divergence, and after becoming excessively minute, are lost at the juncture of the external tissue; a few, however, terminate by forming loops. The dimensions of the dentinal tubes vary at different parts of the same tooth. At the lower part of the pulp-cavity the tubes destined for the anterior and posterior surfaces have a diameter of the 6000th of an inch, while those that proceed from the upper and narrowed part of the pulp-cavity, and from the central line of the solid part of the tooth, seldom exceed the 14,000th of an inch, and are often reduced to a scarcely perceptible line. Usually they do not preserve this small size, but quickly dilate to the 10,000th or 12,000th of an inch; these conditions are not however peculiar to the teeth of this group. The tubes that form the posterior part of the incisors give off branches pretty freely throughout the whole of their course, and when near the surface break up into a rich plexus of anastomosing tubules, in addition to which they occasionally dichotomize. Many of the earlier branches are small and short, but a few are large, go off at a right angle, and may be traced for some distance crossing the course of the neighbouring tubes. In the median line of the sides of the tooth, independent of the secondary curves or undulations, the dentinal tubes pursue a tolerably straight course, as do those in the median line of the anterior and posterior surface. But the dentinal tubes of the anterior halves of the sides describe one large curve, the convexity of which is turned towards the anterior surface of the tooth; and those composing the posterior part of the tooth follow a similar curve, the convexity of which is directed towards the posterior surface; similar relations between the tubes and the several parts of the incisor may be observed in the teeth of other rodents.

Professor OWEN*, when treating on the teeth of rodents, says, "The substances of the incisor diminish in hardness from the front to the back part of the tooth; the enamel consists of two layers, of which the anterior and external is denser than the

* Odontography, page 399.

posterior layer." He does not however anywhere state that the incisors of Sciuridæ have any structural peculiarity resident in the enamel, by which their teeth are distinguished from those of other rodents; neither am I aware that any subsequent author has noted its existence. Nevertheless so great a peculiarity exists throughout this family of Rodents, that a vertical section of an incisor, either of a *Sciurus*, *Pteromys*, *Tamias* or *Spermophilus*, may be recognized at first sight as belonging to the family Sciuridæ.

It has been usual to describe the enamel fibres from the view obtained in a longitudinal section of the tooth, from which circumstance the true structure has not been recognized. The supposed fibres are composed of layers of fibres, and each layer of a single series, the fibres of which are parallel to each other, and at right angles with those composing the layers immediately above and below. In the outer part of the enamel the fibres of all the layers become parallel, and the lamination ceases.

The enamel layers, as seen in a vertical section of an incisor of *Sciurus niger*, and portrayed in fig. 6, are about the 6000th of an inch in thickness, and have straight and even margins. They form a right angle with the surface of the dentine, increasing slightly in thickness in their course outwards (fig. 6 E). Each layer is composed of a single series of squarish fibres, laid side by side, and closely united. During the first part of their course they are straight and parallel, and proceed to the right in one layer and the left in the next, at such an angle as to produce a square pattern over the inner part of the enamel. The appearance thus produced in the central part of the enamel of a transverse section is shown in fig. 7 E. On the side of the incisor the decussation is less strongly marked, and at the thin terminal edges is almost lost. The fibres, after traversing in a diagonal course in the horizontal plane of the tooth two-thirds of the thickness of the enamel, turn abruptly upwards and outwards at an angle of 45 degrees with their original direction. In this, the outer third of their course, the whole of the fibres become parallel, and in proceeding outwards make a gentle curve, the convexity of which is turned towards the cutting edge of the tooth. In the change of direction, the fibres which have followed a diagonal course make an angle not only in the vertical, but in the horizontal plane of the tooth, while those situated near the terminal edge of the enamel are bent in the vertical plane only.

The colouring matter resident in the enamel of the incisors of squirrels, is seen in a thin transverse section to be confined to the outer third, and looks like a stain in the terminal ends of the fibres, which diminishes in intensity from without inwards until it is lost.

In a vertical section through the centre of an incisor, viewed by transmitted light, the superimposed laminæ of enamel fibres will, to an inexperienced eye, appear as parallel fibres; a little patience will however enable the observer to see that they are composed of fibres cut obliquely (fig. 6 E). In places, faint transverse markings will be seen, which indicate the oblique sections of the fibres. Not unfrequently, however, the lateral union of the fibres is so perfect, that in the layers near the cutting edge of

the tooth no transverse marking can be traced. If a section be made obliquely in the vertical plane of the tooth, so as to cut the fibres of one set of layers in their length and the others transversely, we shall have straight fibres with intervening rows of fibres cut across (fig. 8 E). If the section be taken from the protruded portion of the tooth, the cut extremities will be nearly square; but if it be taken from near the base, where the enamel has not attained its full solidity, they will have a less regular outline. Sections of this kind show that the fibres are a little longer than broad, and that the longer axis is placed in the length of the tooth.

A vertical section will however show most strongly the peculiarities that belong to this family of rodents, namely, the small relative amount of enamel, the uniform character of the layers, the uniform lines that mark their junction, and their straight and rectangular course outwards from the surface of the dentine, together with the angle at which they are bent in the external portion of the enamel.

An incisor in which these several conditions of the enamel are found to exist, may I think be safely pronounced to belong to a species included in the family Sciuridæ, and in all probability a member of the genus *Sciurus* or *Pteromys*.

The molar teeth of *S. niger* present no sufficient peculiarity in the structure of the dentine to render a description necessary. Neither can I find any point of difference worthy of notice in the corresponding teeth of *S. vulgaris*, *capistratus* or *cinereus*. In *S. erythropus* the dentinal tubes are continued, the 1500th of an inch, into the enamel, and in this short course branch in the manner shown in fig. 11 E. I have not found this peculiarity in any other squirrel which has come under my notice.

The cementum of the molar teeth is not very abundant, even at the extremity of the fang; I cannot discover that it is continued over the surface of the enamel. If a vertical section of a molar tooth from either of the species I have named be carefully examined, it will be seen that the cementum, where it commences in a thin layer, at the neck of the tooth is composed of uniform rods, directed from without inwards and a little downwards. When this tissue is thicker the rods are seen near the surface, but are lost amongst the lacunæ and their canaliculi. The cemental rods are subgranular in structure, and exceed the enamel fibres in dimension. They average the 3450th of an inch in diameter, and are portrayed in fig. 10 C. I am not aware that this character of the cementum has been previously noticed, it is not however confined to the molars of the Sciuridæ.

In the molar teeth of Squirrels the enamel is far less peculiar than in the incisors, and offers no strongly marked characters by which the teeth can be recognized. The fibres are less regular in form, less clear and transparent, and less free from minute cells than in the front teeth; neither have we a terminal portion taking suddenly an altered direction; nor is there any evidence that the fibres are arranged in parallel layers transverse to the long axis of the tooth. Their course is however, throughout, more or less waved; and although many cross each other, yet all do not; and when they do, the definite and constant angle preserved in the incisors is not observed in the molar

teeth. A vertical section of a molar of *S. niger* exhibits the usual characters of the dental tissues in these teeth (fig. 9). In *S. cinereus* the enamel fibres are in a vertical section, seem to be minutely granular, well-marked, and subject to one or two gentle curves near the surface; they are in the outer part of the tooth very strongly marked, from being highly granular, and less perfectly united laterally than in some other teeth.

Tamias Lysteri, RICH. (Zoological Society).—I have been able to procure a lower incisor only of this creature. The structure of the tooth very closely resembles the incisors of squirrels: the dentine is similar, as are the enamel layers both in shape and arrangement; and the component fibres of the contiguous layers cross each other at the same angle. The decussation however ceases, and the parallel arrangement is assumed in about the middle of the enamel; this difference, if found constant in all the species, will serve to distinguish the *Tamias* from the Squirrels.

Spermophilus (Zoological Society).—The structure in the incisors of this animal deviates a little from that in the Squirrels; in thickness, the enamel, as seen in a transverse section, is about 300th and the dentine the 12th of an inch; the dentine is much the same as in the genus *Sciurus*, excepting that the dentinal tubes of the anterior half of the tooth measure about the 7500th of an inch in diameter, while in the posterior half they average the 6000th of an inch: the enamel is different, and advances a step towards another type. The enamel layers incline upwards at an angle of 78° , instead of preserving the rectangular position, and they are less regular in their course, and less uniform in size than in the former genus. A transverse section shows that the component fibres of the adjoining layers decussate one another throughout the inner half of the enamel, and then become parallel. An oblique section in the long axis of the tooth will expose alternate straight fibres and rows of ends of fibres cut transversely; and in the latter it may be observed that they have an oval rather than a square section, the long diameter of which is one-third greater than the short; this is best seen near the cutting edge of the tooth. If the section be taken from near the base, the fibres in their transverse section are more circular, less compressed, and much less intimately united to their fellows, while at the opposite extremity of the tooth they are so closely connected, that in places the enamel seems a dense transparent structureless mass.

The enamel layers in a vertical section have a thickness of about the 5000th of an inch. In a transverse section, the fibres have a diameter of about the 10,000th of an inch in their smaller, and the 5000th in their greater diameter.

Arctomys Empetra, SCHREB. (Zoological Society).—In a lower incisor the enamel has an average thickness of 75th of an inch, and the dentine the $\frac{3}{10}$ th of an inch. The dentinal tubes have an average diameter of the 10,000th of an inch: I do not find any difference in the dimensions of the dentinal tubes at the anterior and posterior parts of the incisor. They terminate at the enamel in a peripheral layer of minute irregular cells, much in the manner shown in fig. 12 and 13. Those directed towards the back

part of the tooth, in the terminal fifth of their course, form a rich plexus of branches, and finally terminate in minute irregular cells. Then comes a thin investment of transparent cementum, which terminates at the margin of the enamel. The dentine is dotted throughout with fine cellular markings, which seem to indicate the form of the cells of the dentinal pulp previous to its calcification, and give a coarse appearance to the tissue. The dental tissues of this tooth are not distinguishable from those of the next species.

Arctomys pruinosus, GMEL. (Zoological Society).—In an upper incisor the enamel averages the 75th, and the dentine the 5th of an inch; as the dentine closely resembles that of the Quebec Marmot, the description need not be repeated. The enamel exhibits a considerable departure from that of the Sciuridæ, though not wholly different in type of structure. The fibres in the first part of their course are arranged in parallel layers, which have a thickness of about the 4580th of an inch, as seen in a longitudinal section and illustrated in fig. 12 E. The layers lie at right angles with the surface of the dentine, and extend across the inner two-fifths of the enamel, at which point the uniform lamelliform arrangement is broken up by a change in the direction of the component fibres. In a transverse section of the tooth the component fibres of the enamel layers are seen arranged in a single series, lying side by side, and crossing those of the adjoining layers at an angle so as to form a diamond pattern over the inner part of the tissue (fig. 13). The decussating fibres of the superimposed layers, after traversing the inner two-fifths of the enamel, change their direction, become more parallel, and in waved course advance upwards and outwards till they reach the surface of the tooth. But although the course is much more parallel in the outer three-fifths than in the inner two-fifths of the enamel, yet if the focus of the instrument be carefully changed, alternate layers of fibres may be seen crossing each other at an angle to form very elongated and irregular diamond-shaped figures.

The line at which the change of direction takes place is not definitely marked as in the Sciuridæ and many other rodents. In a longitudinal section, it will be seen that the fibres in the terminal part of their course are directed upwards at an angle of 70° with the surface of the dentine, and that small cells are scattered through this part of the enamel. In addition to these minute irregularly disposed cells, lines of cells may be seen commencing at the surface of the dentine, pursuing a curved course, and finally crop out at the surface of the enamel: I have not seen similar out-cropping lines of cells in the enamel of any other rodentia teeth. The enamel fibres may in a transverse section be traced through the coloured portion of the enamel to the surface of the tooth.

Castor fiber, LINN. (Zoological Society).—In an upper incisor the enamel is about the 100th and the dentine the 5th of an inch in thickness.

It has been observed by Professor OWEN, that vascular canals are continued from the pulp-cavity a short distance into the dentine. In the specimen before me, the middle third of the dentine is traversed by vascular canals, which turn short upon

themselves and return to the pulp-cavity not far from whence they started. The canals in radiating from the pulp-cavity pass directly outwards and a little upwards parallel with the course of the dentinal tubes, excepting where they turn to reverse their course, in doing which they do not occupy more than twice or thrice their own diameter. I have not observed that they ever branch or anastomose with neighbouring canals; many indeed so quickly return to the pulp-cavity, that there would scarcely be space enough for branching, while others advance a considerable distance.

The dentinal tubes destined for the anterior part of the tooth commence with a diameter of about the 7500th of an inch and give off branches in the earlier part of their course, which connect themselves with the vascular canals. The disposition to branch ceases however after they have passed the vascular portion of the dentine, and is not resumed until they come near the enamel, when they form a plexus, towards the surface of which is a layer of elongated cells, placed obliquely both to the course of the tubes and the surface of the dentine; the cells are shown in their relative position in fig. 14. Previous to the formation of the peripheral plexus, the dentinal tubes make several curves in a contour line with the length of the tooth. This point is not shown in the figure, as it occurs internal to the part represented. The dentinal tubes of the posterior part of the tooth commence with a diameter of about the 6000th of an inch.

The vascular canals measure from the 750th to the 2500th of an inch in diameter. Those situated near the worn surface are the smallest, from being lined or filled with a transparent tissue, into which the branches of the dentinal tubes do not penetrate.

In the enamel we find a further deviation from the Sciuroid type than was observed in the Marmots. The layers of enamel fibres no longer lie at a right angle with the surface of the dentine, but are directed upwards at an angle of 60° , and moreover describe a slight sigmoid curve, which terminates a little short of the centre of the enamel, from whence the fibres become parallel and proceed at an angle of 30° with the surface of the dentine. These appearances are best seen in a longitudinal section, and are shown in fig. 14 E. In a transverse section made parallel with the course of the layers, as seen in a longitudinal section, the arrangement of the fibres composing the layers becomes apparent. Each layer is composed of a single series of fibres, which pass in straight lines alternated to the right and left in the adjoining layers, and produce an infinite number of minute square tracings over the inner portion of the enamel. When near the middle the decussation ceases, the fibres become parallel and proceed upwards and outwards; but instead of proceeding directly outwards, they bear towards the median line of the skull, as shown in fig. 15. In examining the fibres in the terminal part of their course, a section must be made parallel with their length.

The enamel fibres, as seen in a transverse section, measure about the 6000th of an inch, and may be traced to the surface.

Professor OWEN says, "In a transverse section of the incisor (of the Beaver), the

distinction between the two layers of enamel is still more obvious: the fibres of the inner half, being cut across, give the appearance of fine decussation, oblique lines; while those of the outer half run transversely to the surface, and are crossed by traces of concentric layers*." That the appearance of decussation here mentioned is due to the crossing of fibres, and not to the direction of the section, is proved beyond doubt by taking a thin transverse section and breaking it across the centre, when the fibres of the layers included in the section may be viewed projecting from the broken edges; or it may be even more distinctly demonstrated by removing a little of the partially calcified enamel from the lower portion of the tooth, and placing it with a drop of water between two pieces of glass.

In the dentine of the molar teeth of the Beaver, I can find no characteristic peculiarity that needs description. The root of the tooth is composed partly of cementum, into which the dentine graduates, and through which vascular canals lead to the pulp-cavity.

The fibres of the enamel correspond in arrangement with the external portion of those which form the enamel of the incisor teeth, and like them have a greater and less diameter, the former of which is placed in the length of the tooth.

The enamel fibres are usually directed upwards at an angle of 30° with the surface of the dentine, and near the surface curve a little outwards; but they may be found in some parts of the tooth making two slight curves before arriving at the surface.

Near the upper part of the tooth the fibres are so closely united, that the enamel in places seems almost structureless; but toward the roots, and where it is reflected into the depressions, the fibres are sufficiently distinct to be examined and measured.

The enamel, where it attains its greatest thickness, is marked by oblique lines, which proceed from within outwards and speedily crop out on the surface. They appear to result from a difference of density rather than from the presence of minute cells, such as are found in the incisors of the Marmots.

The cementum of the molars is granular, plentifully supplied with lacunæ, and arranged in concentric laminæ round the vascular canals and the roots of the tooth; here and there a slight tendency to the arrangement in rods, similar to that of the Sciuridæ, may be observed.

Spalax typhlus, PALL. (Zoological Society).—This animal, though placed by Mr. WATERHOUSE in a section between *Murina* and *Arvicolina* in the family MURIDÆ, resembles the Beaver in the structure of the enamel more closely than any other animal, which circumstance offers a sufficient reason for describing the dental tissue in this place.

In an upper incisor the dentinal tubes present an oval transverse section with the long diameter placed in the long axis of the tooth. The long diameter attains the 5000th, while the short diameter does not exceed the 10,000th of an inch. In their passage outwards they describe a sigmoid curve, with the general direction a little

* Odontography, page 407.

upwards, and from their commencement at the pulp-cavity give off rectangular branches which take a downward course. When near the enamel, the dentinal tubes bend upwards and emit branches from the convex surface only, as shown in fig. 16 D. These are lost at the junction of the enamel and dentine, and terminate without the presence of peripheral cells, such as are found in the Beaver.

The enamel in the inner part of the tissue is arranged in transverse layers, which in a longitudinal section are seen to proceed from the surface of the dentine at an angle of 73° . Each layer measures about the 6000th of an inch in thickness, and extends about half-way to the surface, where the component fibres of the different layers assume a more parallel arrangement. The layers in a favourable section have even margins, but if the section inclines slightly from the centre of the tooth in either direction, the margins will be a little irregular; indeed this observation applies with equal force to similar sections of other rodentia teeth.

In a transverse section the contiguous layers cross each other at a right angle, and at places look as though plaited, as in the Sciuridæ. In the outer division of the enamel, the fibres proceed in straight lines to the surface (fig. 17). An oblique section in the length of the incisor will expose alternate layers of straight fibres, and fibres divided transversely; the appearances thus produced are delineated in fig. 16 A. On the whole, the enamel is more transparent and the structure is less distinctly marked than in any other incisor I have as yet described; indeed the peripheral division in a longitudinal section frequently seems structureless.

The enamel varies a little in thickness in different parts of the tooth, the average being about the 200th of an inch, the inner or decussating and outer or parallel being nearly equal in breadth.

The rooted molars of the Spalax present a slight structural resemblance to those of the Sciuridæ. The dentinal tubes leave the pulp-cavity with about the 7500th of an inch, which is preserved till they arrive near the enamel. In the upper and middle part of the tooth the tubes describe a sigmoid curve in passing outwards, and give off branches during the two outer thirds of their course. In a longitudinal section, the enamel is seen to be composed of fibres which pass upwards and outwards with a slight curve, and have a diameter of the 6000th of an inch.

The cement resembles that of squirrels' molars in being composed of rods arranged transversely to the length of the tooth.

In the family MURIDÆ of WATERHOUSE*, a distinguishing character in the enamel runs through the various sections, excepting the three first, the fifth and seventh, and in the first of those (genus *Myoxus*) it exists partially. The teeth of the Dormice are in structure intermediate between those of the Squirrel-tribe and the Rat-tribe. The incisors of the Jerboas are however wholly different from any other members of this family, and the incisors of Bathyergina resemble those of the Hystricidæ. The Spalax I have already described.

* Johnston's Physical Atlas.

Myoxus avellanarius (LINN).—In the upper incisors of the Dormouse may be observed the first indications of the peculiar arrangement of the enamel layers, which holds in the great majority of the members of the family Muridæ.

The arrangement of the component layers of the enamel is, however, not alike in the incisors of the upper and lower jaws ; hence a description of each is needed.

In the upper incisors, the enamel is composed of flexuous layers of fibres arranged transversely to the long axis of the tooth. In a longitudinal section each layer is seen to proceed upwards, then obliquely outwards, and afterwards again upwards, the general direction being at an angle of 70° with the surface of the dentine. The layers have serrated margins through the first curve, but during the after part of their course the margins are even, as in the Sciuridæ. The layers, after extending the 500th of an inch across the enamel, are broken up and the fibres are continued in parallel lines through the 750th of an inch to the surface, and at an angle of 30° with the surface of the dentine : these characters are shown in fig. 18 E.

The enamel layers are subject to a little variety in thickness, the average being about the 7500th of an inch ; and here and there a layer may be found which gradually diminishes till it comes to a point and is lost before reaching the external portion of the enamel. An oblique section in the length of the tooth may be made at such an angle as to expose one layer of fibres in their length and the adjoining layer cut transversely. This view is shown in fig. 19. It will be seen that the fibres have a greater breadth than thickness.

In a transverse section the component fibres of one layer are shown crossing those of the layer above and below at a right angle, thus producing a square pattern over the lamelliform portion of the enamel, which is represented in fig. 20. The fibres give a transverse measurement of the 8823rd of an inch. The fibres in the outer division of the enamel are straight, and lean obliquely towards the median line of the skull.

In the lower incisors of this little creature the position of the enamel layers is reversed. A transverse section exhibits them extended in the length of the tooth, presenting an appearance similar to that seen in a longitudinal section of the corresponding upper tooth, excepting that they make but one curve with a flattened and slightly enlarged middle portion (fig. 22). A longitudinal section of a lower incisor presents an appearance similar to a transverse section of the corresponding upper tooth, as shown in fig. 21.

The dentine of the incisors of the Dormouse is not sufficiently peculiar to render a minute description necessary. The tubes are perceptibly larger at the lower than at the upper part of the tooth, and those in the posterior half of the tooth retain their full dimensions till near their termination.

The enamel is about the 300th, and the dentine the 23rd of an inch thick.

In the molar teeth, the lamelliform arrangement of the enamel exists in a perceptible degree near the terminal edge only, and so far establishes a resemblance to the molars of the Rat-tribe. The dentine offers no peculiarity worthy of notice in this communication.

Jerboa Ægyptius.—The teeth of this animal present great structural peculiarities. The upper and lower incisors are subject to the same difference in the arrangement of the lamellæ of the enamel as the corresponding teeth of the Dormouse; while the molars resemble in structure the teeth of marsupial animals. In the long axis of a transverse section of an incisor, the enamel measures the 150th and the dentine from the 17th to the 20th of an inch.

The dentinal tubes radiate from the pulp-cavity without exhibiting a specific peculiarity. Many of those distributed to the anterior as well as those to the lateral and posterior parts of the tooth, dichotomize once or twice in the early part of their course, and afterwards give off small branches. When near the enamel the dentinal tubes break up into a rich plexus of branches, many of which uniting, form a series of loops, and give a greater opacity to this than to any other part of the section. External to this plexus the dentine is comparatively transparent and traversed by a diminished number of dentinal tubes, a few of which are continued into the enamel; these, after following the course of the lamellæ, are lost in the peripheral portion of that tissue. The dentinal tubes at their largest parts do not exceed the 7500th of an inch.

The peculiar character of the enamel of the upper incisor is best seen in a longitudinal section, in which the lamellæ are shown proceeding from the dentine in straight lines directed obliquely upwards at an angle of 60° . In this section each layer appears slightly fibrous and a little indefinite in outline; in both respects differing from the teeth of this and the preceding family. These conditions are partly due to the presence of tubes continued from the dentine, and are portrayed in fig. 23.

The layers, after proceeding for about the 250th of an inch across the enamel, suddenly change their direction, and the component fibres lose the lamelliform arrangement, become parallel, and in tolerably straight lines pass upwards at an angle of 21° with the surface of the dentine. In this, the external part of the enamel, the tissue is very transparent, the fibres are rather indistinct, and the indistinctness increases the nearer we approach the worn extremity of the tooth. Here and there one or two tubes may be seen emerging from the lamelliform portion, and advancing into the outer transparent part of the enamel, but they are soon lost in their own minuteness.

An oblique longitudinal section may be so made as to expose alternate layers of fibres cut in their length, and the intervening ones cut transversely. The latter are oval, and present a long diameter of about the 5550th and a short diameter of about the 8824th of an inch. And it will also be seen, that although the fibres have their long axes placed in the length of the tooth, and hence transversely to the adjoining fibres longitudinally exposed, yet that the long axes are not at a right angle or any constant angle with them, but present various degrees of obliquity, as shown in fig. 24. This want of regularity in the arrangement of the fibres no doubt contributes to the fibrous appearance of the layers in the longitudinal section of the tooth, in which the component fibres are of course cut across with various degrees of obliquity.

In a transverse section of an upper incisor the fibres of the alternate layers are

seen crossing each other at something short of a right angle; in the inner and in the outer part of the enamel they are seen proceeding in straight lines to the surface, without inclining to either side.

A thin layer of cement may be distinguished on the posterior part of the tooth, but is lost when it has passed over the terminal edge of the enamel.

In the lower incisors of the *Jerboa* the enamel lamellæ are arranged in the long axis of the tooth, much in the same manner as in the corresponding teeth of the *Dormouse*. A longitudinal section will expose the decussation of the fibres of the contiguous layers, the one set proceeding upwards and outwards, and the other downwards and outwards. The fibres in the external division of their course lose the lamelliform arrangement and proceed upwards and outwards in a gentle curve (fig. 26).

An oblique section in the length of the tooth will cut across the layers in their breadth, and show them arranged in lines parallel with the surface of the dentine. Each layer has in this view a denticulated margin, similar to the lamellæ in the *Rats*.

A transverse section of a lower incisor exposes the enamel lamellæ divided transversely to their length. Those which arise from the median side of the tooth are directed forwards and towards the median line, while those that start from the anterior and outer surface of the dentine, are directed in a curved line outwards in an opposite course. Each layer thickens slightly as it advances outwards, and exhibits slightly serrated margins.

The component fibres have their long axes placed obliquely (fig. 28). Transverse sections made with different degrees of obliquity, will give variety in the appearance of the enamel layers. Thus a longitudinal section of one set of fibres, and a transverse section of another may be obtained, as partly shown in fig. 28. But if the section be oblique to each axis of the tooth, the enamel may present a confused intersection of lines, from which little or nothing can be made out. This observation may be applied with equal truth to similar sections of other rodential teeth.

The dentinal tubes in the lower incisor are oval in section, and have the long diameter placed transversely to the length of the tooth, hence they appear larger in the transverse than in the longitudinal section (figs. 26 and 28). In the molar teeth, the dentinal tubes leave the pulp-cavity for the crown of the tooth with a diameter of about the 10,000th of an inch, and are very closely packed. They give off very few, if any branches, till near the periphery of the dentine, and here they are far from numerous, as compared with those seen in other molar teeth. The branches are short and bristle-like, and the parent tubes, or a large branch, is usually continued into the enamel. The dentinal tubes of the fangs commence with a similar diameter to those of the crown of the tooth, but they speedily dilate to the 7500th of an inch, and give off branches during the greater part of their course.

Previous to entering the enamel the dentinal tubes are reduced to about the
MDCCCL.

15,000th of an inch, which dimensions are retained after they have passed with that tissue. The tubes pass onwards with slight tortuosities in a line with the direction of the enamel fibres, until they reach the outer third, when they are lost or turn suddenly at a right angle, and after advancing a short distance downwards, disappear. These conditions are shown in fig. 29. The fibres of the enamel show no disposition towards a lamelliform arrangement, excepting near the terminal edge, where the lamellæ have, in a longitudinal section, serrated margins. The fibres leave the surface of the dentine on the sides of the tooth at an angle of about 50° , and in the outer third of their course come a little outwards. In the depression on the masticating surface, they proceed at a right angle from the surface of the dentine.

The molars of the Jerboa, though like those of marsupial animals in having the dentinal tubes continued into the enamel, differ from them in having serrated lamellæ in the enamel near its terminal edge, and hence may be distinguished both as not belonging to the marsupial order, and as belonging to the Muridæ.

I have been obliged to make upwards of twenty sections of the teeth of this interesting animal before I could fully satisfy myself on the various points of the dental structures; indeed in the early part of the investigation I despaired of making out the arrangement of the component fibres of the enamel.

The next animal on the list is *Pedetes Cafer*, but as the teeth resemble more closely the teeth of the Hystricidæ than any other group of animals, and are altogether dissimilar to those of the Muridæ, I shall postpone the description till I have gone through my specimens of Hystricine rodents.

The teeth which have come within my reach from members of the following genera, *Mus*, *Hapalotis*, *Gerbillus*, *Hydromys*, *Hesperomys*, *Arvicola* and *Lemmus*, so closely resemble each other in the general characters of the structure of the dental tissues, that it will be necessary to describe minutely those of a typical species only, and afterwards to note any specific differences that are found in teeth from other members of these genera. I will therefore take the teeth of the common Rat (*Mus decumanus*) as being typical of the family, and also on account of the ease with which the teeth may be obtained by any subsequent observer.

Mus decumanus.—From a longitudinal section of a lower incisor, we learn that the dentine presents no specific or generic peculiarities. The dentinal tubes from their commencement give off numerous minute pilose branches, and terminate near the surface of the dentine by forming a dense plexus of minute ramifications. Their course is straight, or nearly so, excepting the secondary undulation, which exists in a greater or less degree in almost every specimen of dentine that has come under my observation. The tubes are oval in their transverse section, having a short diameter of about the 15,000th of an inch, and a long diameter which is placed in the length of the tooth, and averages the 10,000th of an inch.

In the anterior part of the tooth the tubes gradually diminish in diameter from their commencement, while those in the posterior part retain their original size till

near their termination, when they form a plexus, but less dense than that in the anterior part of the tooth.

The enamel is seen to be composed of fibres arranged in serrated lamellæ, which leave the surface of the dentine with a short but gentle curve, and then proceed upwards and outwards in nearly a straight line till about to terminate in the outer division of the enamel, when they make a slight sigmoid curve with the terminal portion directed upwards, their general course being at an angle of 50° with the surface of the dentine (fig. 30).

At the outer fifth of the thickness of the enamel the layers are broken up, and their component fibres take a parallel course upwards and outwards, and with a slight curve, which is strongest near the outer extremity, when they reach the surface of the tooth, their general courses being at an angle of 30° with the surface of the dentine.

Each lamella commences at the surface of the dentine with a diameter of about the 7500th of an inch, which gradually increases till at the distal extremity it attains the 6000th of an inch. The margins of the lamellæ are strongly serrated, and the projections of one layer fit into corresponding depressions in the contiguous lamellæ. This peculiar form and arrangement, as exhibited in a longitudinal section, may be regarded as typical of the enamel of this family of Rodentia.

In an oblique transverse section cut nearly parallel with the worn surface of the tooth, it may be seen that each layer is composed of a single series of enamel fibres, and that the fibres of contiguous layers cross each other at such an angle as to produce a diamond pattern over the lamelliform portion of the enamel; and also that the fibres curve a little in their course outwards (fig. 31). The upper and lower surfaces of the component fibres of each lamella appear to be a little uneven, and these irregularities no doubt contribute to the development of the serrations observed in the longitudinal section of the tooth, but in the section now under consideration these appearances are seen but obscurely. When the crossing sets of fibres have arrived within the 750th of an inch of the surface, the decussation ceases and they proceed outwards in parallel lines directed obliquely towards the median line of the skull; and in the latter 3000th of an inch of their course they turn directly outwards in a line with the long axis of the section.

If a section be so made as to display one set of fibres in their length, and the adjoining ones divided transversely, the latter will exhibit an oval section, while the former are seen to be armed with minute processes which fit into the small interspaces that would otherwise be left between the non-touching surfaces of the oval fibres. These conditions are shown in fig. 32. To these lateral processes the serrated margins of the lamellæ, as seen in the longitudinal section, are due, as are the irregularities of surface seen in the transverse section.

The outer ends of the enamel fibres are best seen in the middle and lower part of the tooth. Near the cutting edge, in the outer portion of the enamel, the union between

the component fibres is so perfect that all appearance of structure is lost. This observation applies equally to other scalpriform teeth. The coloured surface presents the character of a stain, through which the fibres are continued. If the section be tolerably thick and a little oblique, the two cut edges will give the appearance of a coloured lamina. But the structure of the enamel may be demonstrated, though in a less complete manner, by taking a little of the soft partially developed tissue from the base of the tooth, and with a little water placing it between two slips of glass. The decussation of the fibres will be then shown, and some will present a beaded outline; small portions may also be found in which development is more forward, and some of the fibres armed with small lateral processes will appear in the field of the microscope. Some of these appearances are shown in fig. 33.

The upper have a somewhat thicker coat of enamel than the lower incisors; it averages about the 211th of an inch, of which the lamelliform portion occupies about the 333rd and the outer or fibrous portion the 666th of an inch.

In a longitudinal section the lamellæ leave the surface of the dentine at an angle of 55° , which is a little wider than that formed by the corresponding parts in the lower incisors. The layers describe a gentle curve upwards and outwards, and the margins are serrated through the greater part of their course, but less strongly than in the corresponding lower teeth; in addition to which the layers are frequently marked by transverse lines. Towards the outer part of their course, the serrations become faint and ultimately give place to a smooth outline. The fibres in the outer part of the enamel run at an angle of 25° with the surface of the dentine.

In the molar teeth the dentine presents no generic peculiarity, neither does the enamel about the cusps of the teeth, but at and near its terminal edge on the neck of the tooth, the lamelliform arrangement with the serrated edges holds good, both in the Rat and in other rooted molars of the genera *Mus*, *Hapalotes*, *Hydromys* and *Hesperomys*. The cementum about the neck of the tooth is arranged in rods, similar to those already described in the corresponding teeth of the Squirrels.

The teeth of *Mus rattus* present no structural peculiarities by which they can be distinguished from *M. decumanus*, neither do those of the following rodents, excepting in size:—*Mus Alexandrinus*, *sylvaticus*, *musculus*, *minutus* and *fusipes*. In examining the molar teeth of *Mus giganteus*, I find a peculiarity which may perhaps be specific. The fibrous enamel on one side of the cusps is separated from the dentine by a layer of perfectly transparent and apparently structureless enamel, which is thickest near the apices of the cusps, and gradually thins till it is lost at the bottom of the fissures. On the sides of the tooth the serrated laminæ of the enamel are strongly marked, and extend through a larger portion of the tissue than is common in the corresponding teeth of any other rat which I have examined.

In the teeth of *Hapalotes albipes* and *longicaudatus* of New South Wales, I find a very close structural resemblance to those of the Rat, the principal difference being in the more blunted shape of the serrations of the enamel lamellæ, and the greater

frequency and strength of their transverse markings. In a longitudinal section of a lower incisor the layers leave the dentine at an angle of 40° , and have a thickness of about the 7500th of an inch. The whole thickness of the enamel is about the $\frac{1}{1500}$ ths of an inch, of which $\frac{1}{1500}$ ths is occupied by the lamelliform, and $\frac{2}{1500}$ ths by the outer or fibrous portion of the enamel. The latter lies at an angle of 15° with the surface of the dentine.

It will be seen, on referring to the description of the corresponding teeth and sections of *Mus decumanus*, that the angle at which the laminæ of enamel fibres leave the surface of the dentine, is sufficiently different from that in the *Hapalotes* to distinguish the teeth of these creatures from each other.

The molars of the *Hapalotes* resemble those of the Rat. I am indebted to the kindness of Mr. GOULD for an opportunity of examining the teeth of these animals.

Gerbillus Shawii (DEVERN.) stands next on my list. The dentine of the incisors of this small rodent is peculiar in having a few vascular canals extended from the pulp-cavity a short distance into its substance, which in a transverse section gives an uneven outline to the surface of the pulp-cavity. The dentinal tubes give off branches throughout the whole of their course, are interspersed with small cells, and are subject to irregular secondary undulations; in addition to which, the whole substance of the dentine has a cellular appearance as though the developmental cells had retained their outline during the process of calcification, instead of becoming confluent and homogeneous.

In a longitudinal section the laminæ leave the surface of the dentine at an angle of 55° , and curve upwards and outwards through about $\frac{6}{1500}$ ths of an inch: they then give place to the fibrous portion in which the fibres curve upwards and outwards, their general course being at an angle of 20° with the surface of the dentine.

The laminæ are bordered by blunt serrations, and are subject to transverse markings, in both particulars resembling the enamel of the corresponding teeth of the *Hapalotes* more closely than that of the Rat.

In a transverse section the enamel of the incisors could not be distinguished from that in the Rat.

In the molar teeth the dentinal tubes are continued into the enamel the 1500th of an inch. In no part of the latter tissue could I distinguish a lamelliform arrangement in the enamel.

The teeth of *Hydromys chrysogaster* of New South Wales resemble those of the Rat. The incisors of the Hamster, *Cricetus fumentarius* (PALL.), can scarcely be distinguished from those of *Mus decumanus*.

Hesperomys Darwinii (WATERHOUSE) possess teeth so like in minute structure to those of *Mus decumanus* that a special description is unnecessary.

Geomys umbrinus (RICH.), though not placed by Mr. WATERHOUSE in the family Muridæ, have incisors so Rat-like, that it would require the presence of sections of the teeth of this creature and of the Rat to distinguish the one from the other, and even then there would be some difficulty in finding characteristic differences

sufficiently well-marked to render the conclusion trustworthy if any doubts were thrown on the authenticity of either of the specimens.

Arvicola amphibius (LINN.).—It would be extremely difficult to point out the characters by which sections of the incisor teeth of this creature could be distinguished from the corresponding ones of several teeth I have already described, especially those of the common Rat (*M. decumanus*). The serrated enamel lamellæ leave the dentine at nearly the same angle; the serrations are perhaps finer and less strongly marked, and the lamellæ are more frequently crossed by equidistant transverse lines. The rootless molar teeth, however, are sufficiently different from those of the Rat. In a longitudinal section, it will be seen that on one side of each denticle the enamel is composed of an inner lamelliform portion, with the edges of the lamellæ serrated as in the incisors, and another portion in which the enamel fibres are parallel; while on the opposite and posterior surface of the denticles the lamellæ are absent, and the enamel fibres pass across the structure in a curved line to the surface. In a transverse section, it is seen that the two conditions pass insensibly into each other at the bottom of the longitudinal grooves, where the component denticle coalesces, and also immediately behind the longitudinal ridges which mark the sides of the teeth.

In the Field Vole, *Arvicola nivalis* (MARTIN), the teeth, both molars and incisors, structurally resemble those of the *A. amphibius*.

The incisors of the Bank Vole, *Arvicola glareolus* (SCHREB.), are rat-like; but in the molar teeth the serrated lamelliform arrangement of the enamel is very indistinct. In the lower incisors the serrations of the lamellæ are shallow, while the transverse markings are rather strong. The appearances presented in a longitudinal section are delineated in fig. 34.

The incisors of *Lemmus Norwegicus*, DESM. (Zoological Society), do not offer any structural differences from the preceding group worthy of description.

Fiber zibethicus (LINN.).—This animal is placed by Mr. WATERHOUSE in the family MURIDÆ, section *Arvicolina*. The dental tissues do not well accord with that position, but seem to indicate a nearer relation to the Beaver and Dormouse. In the molar teeth, however, the enamel in places resembles that in the corresponding organs of *Arvicola amphibius* and *A. nivalis*, but the serrated lamelliform arrangement is not as uniform or as well-marked as in those animals. Yet Mr. WATERHOUSE's arrangement of Rodentia is, with but few exceptions, so strongly corroborated by the structure of the dental tissues, that in this case, where there is conflicting testimony in these tissues as to where they should be placed, I shall do well to describe them in the position he has assigned to the animal.

In the upper incisors, a few vascular canals radiate from the pulp-cavity into the dentine, but they are far less numerous, and run a shorter course than in the corresponding teeth of the Beaver. The dentinal tubes resemble those of the latter animal, excepting that they terminate at the enamel, without the presence of a peripheral layer of cells.

A longitudinal section exhibits the enamel lamellæ passing outwards in an irre-

gular sigmoidal curve, their general direction being at an angle of 80° with the surface of the dentine. Immediately on leaving the dentine the layers make a short curve upwards and outwards, during which the margins are serrated; the serrations then become indistinct or altogether cease, and the layers pursue a tolerably straight course till near their termination, when they turn upwards, after which the component fibres become parallel and advance to the surface at an angle of 33° with the dentine.

On looking carefully over a longitudinal section, parts will be found in which the transverse direction of the lamellæ appear to be reversed. Fibres, or layers of fibres, will be seen running for a short distance obliquely in the long axis of the tooth.

In a transverse section the fibres of the alternate layers are seen to cross each other obliquely, so as to produce a diamond pattern over the lamelliform portion of the enamel. In the earlier part of their course the fibres curve a little, but afterwards become straight. In the outer part of the enamel the fibres pass directly outwards without leaning to the one side or the other.

In the lower incisors the structure of the enamel not unfrequently presents a confused appearance, as though the lamellæ were subject to some irregularity in arrangement. In a longitudinal section the enamel layers are seen leaving the surface of the dentine at an angle of 50° , and in their course curve a little outwards. The margins are pretty strongly marked with small oblique serrations and oblique transverse lines. The lamellæ have a thickness of about the 5000th of an inch. The enamel has a thickness of about the $\frac{9}{1800}$ ths, the lamelliform portion of which is about the $\frac{7}{1800}$ ths of an inch. In a transverse section parallel with the course of the lamellæ, the decussation of the alternate layers of fibres may be seen; and in a section a little more oblique, the fibres in the terminal part of their course may be seen passing in straight lines obliquely outwards from the median side of the tooth. In the dentine of the lower incisors, the vascular canals are much less abundant than in that of the corresponding upper teeth.

The confluent denticles of the molar teeth are coated with enamel, which is very irregularly lamelliform, with serrations so indistinctly marked and inconstant, that the appearance scarcely merits the name. A longitudinal section will best exhibit this view. In a transverse section, parts may be found in which the decussation of adjoining layers of fibres is visible, but generally the fibres seem to follow a much less regular and constant course; and in places they are parallel, as in the outer part of the enamel of the incisors. However, when we find the decussation, it will be situated on the anterior surface of the denticles; so far the structure resembles that found in the corresponding teeth of the Water-Rat, and, as in that animal, the enamel on the posterior surface of the denticles is uniformly free from the lamelliform arrangement. Near the masticating surface of the molar teeth the enamel fibres are so intimately blended, that little or no structure can be discerned.

The cementum, in no part of the tooth very abundant, is occupied by very large irregular cells and vascular canals. The latter are very large, have nodulated mar-

gins, and run principally in the transverse axis of the tooth. The tissue of the cementum, as seen in a transverse section, is unusually clear and transparent.

I am indebted to Mr. WATERHOUSE for a list of those rodents which he considers the most typical species of the several divisions of his family Hystricidæ, and have been fortunate in obtaining the teeth of all he has enumerated, excepting *Echimys*.

In the dentine of these teeth, I find nothing that is characteristic of the group. But the enamel is very peculiar, and the peculiarity is constant in each species I have examined. So strongly is the family characteristic marked by the peculiar arrangement of the fibres of this tissue, that it is necessary to have seen the structure in one hystricine tooth only, to be enabled to recognize at first sight the tooth of any other species as a member of the same group. We no longer see in a longitudinal section of an incisor uniform laminæ separated in the lamelliform portion of the tissue by well-defined lines, but in their stead find thick and confluent layers of obliquely placed fibres, which in a transverse section are seen to pursue a serpentine course from the dentine towards the surface, near to which they become straight and parallel as in the corresponding part of the enamel of the teeth previously described. Hence in this as in the preceding group, I need describe minutely the structure of the incisors of one species only. The molar teeth offer greater variety in the arrangement of the component tissues, and may require farther notice.

Hystrix cristata (LINN.).—In the incisors, the enamel attains a thickness of about the 45th and the dentine the 4th of an inch. The latter tissue offers no striking peculiarities; near the enameled surface it is tenanted by obliquely placed elongated cells, similar to those found in the incisors of the Beaver and many other teeth: they are shown in fig. 35 D.

In a longitudinal section, the enamel presents a very beautiful and, as compared with the tissue as it occurs in the preceding families, a very novel appearance. Large confluent laminæ of from the 1000th to the 1500th of an inch in thickness, leave the dentine at an angle of 80°. Each layer is composed of enamel fibres directed obliquely, and the obliquity varies in the adjoining layers, but corresponds in the alternate ones, in the manner delineated in fig. 35 E. But the fibres are not oblique in one direction only; one extremity of each fibre may be traced to dip into or under those of the contiguous layers, while the other extremity is usually cut obliquely across, and exhibits a diameter of about the 5000th of an inch. When within the 250th of an inch of the surface the layers gradually disappear, and their component fibres take a parallel course, and at an angle of 30° proceed to the surface.

In an oblique transverse section parallel with the course of the enamel laminæ, the appearances are even more striking than in the longitudinal one. The enamel looks as though the fibres were thrown into waves, the furrows of which commence at the surface of the dentine, and proceeding obliquely outwards, crop out where the fibres become parallel, and form the external portion of this tissue; their direction is shown in fig. 36. A close inspection of a favourable section will enable the observer

to see that the enamel fibres pursue a serpentine course, and in the lamelliform portion describe three tolerably uniform curves (fig. 36 E.). Then again, by altering the focus of the microscope, without changing the position of the section, it may be seen that the fibres immediately above and below those already observed, pursue a similar serpentine course, but arranged so that the concavities and convexities point in opposite directions, like the two sides of the figure 8. The appearance thus produced is shown in fig. 39, which in this particular must be regarded as a diagram rather than an accurate portrait. This crossing and re-crossing in curved lines, together with the cropping out of the curves of the contiguous fibres, produces a most complex appearance; and if the section be not parallel with the length of the fibres, the structure appears, to one who has not given attention to the subject, so confused as to defy explanation. If the section be so made as to expose in their length the enamel fibres of the middle of the anterior part of the tooth, those near the sides will be cut obliquely and present a penniform arrangement. An oblique longitudinal section will exhibit the fibres of alternate layers divided almost transversely, while those of the intermediate ones are exposed, taking an oblique course: this point is shown in fig. 37. In addition to the peculiarities already enumerated, small rounded cells are scattered through the enamel of this and most other Hystricine teeth.

The dentine of the molar teeth of *Hystrix cristata* is peculiar in having its tubes unusually free from lateral branches during the greater part of their course. The secondary undulations are strongly marked; and on approaching the enamel, the terminal branches are comparatively few in number and large in size, and commonly pass the 750th of an inch into the enamel.

Near the termination of the dentine in the root of the tooth, the dentinal tubes radiate from a number of centres, and the tissue graduates into the cementum, which is very abundant in this situation, and forms a considerable portion of the root.

In a longitudinal section the enamel fibres are seen to proceed upwards and outwards in parallel lines till near the surface, when they assume a similar arrangement to that seen in the incisor teeth. When the enamel is thin, the lamelliform arrangement is scarcely seen; but where it exists in a tolerably thick layer, the confluent laminæ commence near the dentine. It should be remarked that in the Hystricine molar teeth, the usual position of the fibrous and lamelliform divisions of the enamel is reversed. Hitherto we have found the fibrous enamel placed externally; but here and in the succeeding family, the lamelliform enamel occupies the external position in the molar teeth.

Hystrix prehensilis (LINN.).—The incisors in microscopic structure closely resemble those of the common Porcupine. In the molar teeth, the dentinal tubes are continued about the 1000th of an inch into the enamel.

Dasyprocta Aguti (LINN.).—A longitudinal section of an incisor shows that the dentine of the anterior part of the tooth is bordered by a layer of obliquely placed elongated cells, about the 750th of an inch broad. The enamel is composed of con-

fluent laminæ of obliquely placed enamel fibres, which have a diameter of about the 5000th of an inch, while the layers have a thickness of from the 1362nd to the 2150th of an inch, and leave the dentine at an angle of 65° . In the outer division of this tissue the fibres lie at an angle of 35° with the surface of the dentine.

Prof. OWEN describes the structure of the teeth of the Agouti from a longitudinal section of an upper incisor, and says, "The fibres composing the inner and more opaque part of the enamel proceed obliquely, but almost transversely across that substance, with a gentle curve in the opposite direction to the last curve of the contiguous dentinal tubes, viz. with the convexity towards the crown: the fibres of the peripheral layer of the enamel make a slight bend towards the crown; these enamel fibres are as thick as two of the dentinal tubes with their interspaces; their ends are lost in the clear peripheral substance to which the distinct, apparently structureless brown layer of cement is attached, and to which the colour of the convex surface of the incisor is due*."

Had Prof. OWEN made transverse sections of this tooth, he would I think have been led to give a wholly different account of the enamel; he would have seen the waved appearance which closely corresponds with that I have described in the incisor teeth of the Porcupine, and is produced by a similar flexuous arrangement of the component fibres; he would also have seen that the brown colour is resident in, and is due to a stain in the terminal ends of the enamel fibres. The enamel of the molar teeth of this animal resembles that of the corresponding teeth of the Porcupine.

Dasyprocta Acouchy (ERXL.). The dental tissues of this creature closely resemble those of the preceding species.

Cælogenys Paca (SCHREB.).—The dentine of the incisor teeth does not differ very perceptibly from that of the corresponding teeth of the Agouti and Porcupine. It measures about the 5th of an inch, while the lamelliform portion of the enamel is about the 107th, and the fibrous 300th of an inch in thickness. In a longitudinal section the confluent layers of enamel fibres leave the dentine at an angle of 70° , and the fibres in the outer fibrous part of the tissue lie at an angle of 40° . The layers have a thickness of from the 1000th to the 1667th of an inch; and the fibres are about the 5000th of an inch in diameter. In an oblique transverse section the waves of the enamel fibres are more strongly marked than in the enamel of the Porcupine, as shown in fig. 38.

An oblique longitudinal section shows with great distinctness alternate layers of fibres divided more or less transversely, and intermediate ones pursuing an oblique course. Fig. 37 illustrates faithfully this strongly-marked and peculiar appearance.

Capromys Fournieri (DESM.).—The dentine terminates at the enamel without the presence of oblique elongated cells, but small rounded cells are present and intermingled with the terminal anastomosing branches of the dentinal tubes. The dentine of a lower incisor measures about the $\frac{3}{25}$ th, the lamelliform portion of the enamel the

* Odontography, page 404.

83rd, and the external about the 500th of an inch. In a longitudinal section the confluent laminæ leave the dentine at an angle of 55° , while fibres of the outer part are placed at an angle of 20° with the surface of the dentine (fig. 40). The layers have a thickness of from the 1500th to the 3000th of an inch.

Myopotamus Coypus, MOLINA (Zoological Society).—The dentine of the incisors at its anterior termination is occupied by small rounded cells, with which the terminal branches of the dentinal tubes freely communicate, and in addition to which many areolar-shaped cavities exist similar to those found in imperfectly developed human and other dentine*.

The enamel presents the true Hystricine character, but the layers in a longitudinal section are more confluent than in the teeth previously described. They leave the dentine at an angle of 56° , and the fibres in the outer portion of the texture lie at an angle of 40° with the surface of the dentine.

In an oblique transverse section of an incisor parallel with the worn surface of the tooth, the fibres are seen to make four undulations, but they are less deep than those seen in the *Porcupine* and *Paca*. Near the terminal edge of the enamel on the sides of the tooth, in this as in other Hystricine incisors, the fibres make but one or two gentle curves. The confluent laminæ, as seen in a longitudinal section, have an average thickness of about the 1000th of an inch, and the enamel fibres a diameter of the 5000th of an inch.

I find in the enamel of this tooth here and there irregularly rounded interspaces, vacant or occupied by a transparent structureless mass. This perhaps may be a peculiarity confined to the individual specimen. The dentine of the lower incisor has a thickness from back to front of the 3rd, the lamelliform portion of the enamel the 40th, and the external fibrous part the 500th of an inch. The cementum is continued from the sides of the tooth a short distance upon the enamel, but does not blend with the terminal ends of the enamel fibres. On the contrary, the two tissues are separated by a well-defined line.

Octodon Degus, MOLINA (Zoological Society).—In the lower incisors the dentinal tubes of the anterior half of the tooth terminate in fine branches, with which few if any cells are intermingled. The tubes at their commencement in the pulp-cavity are comparatively large, and attain a diameter of about the 5000th of an inch.

The enamel of this small tooth is truly Hystricine in character. The confluent layers leave the dentine at an angle of 45° , which in the outer fibrous part of the texture is reduced to 20° . The 1500th of an inch is the average breadth of the layers, the component fibres of which have a diameter of from the 7500th to the 5000th of an inch. The dentine has a thickness of about the $\frac{3}{5}$ th, the lamelliform portion of enamel the 1,6th, and the external part the 750th of an inch.

In the molar teeth the enamel fibres describe a faint sigmoid curve in their passage

* Lectures on Dental Physiology and Surgery.

outwards, where the tissue exists as a thin layer; but in those parts in which it is more abundant in quantity, the fibres in the external part of their course assume the confluent lamelliform arrangement.

Schizodon fuscus (WATERH.).—In the incisor teeth, a few vascular canals are continued from the pulp-cavity into the posterior half of the dentine. The dentinal tubes branch from their commencement and terminate in the anterior part of the tooth in fine tubules without the presence of peripheral cells. They have a diameter of about the 6000th of an inch.

The enamel has a general resemblance to that described in the last species. The confluent laminae have a thickness of about the 2300th of an inch and leave the dentine at an angle of 50° , which in the fibres of the exterior is reduced to 15° . The dentine has a thickness of about the 15th, and the enamel the 166th of an inch, of which 13 parts are lamelliform and 5 parts fibrous and external.

In the molar teeth the enamel fibres advance one third of their course in parallel lines, and then fall into the confluent lamelliform arrangement, but with less precision than in the incisor teeth.

Spalacopus Paepigii (WAGNER).—The dental tissues of the incisor teeth of this animal resemble pretty closely those of the preceding species. The posterior half is not however permeated by vascular canals. The enamel has a thickness of about the 150th of an inch, of which seven-tenths is lamelliform, and three-tenths external and fibrous. The inner part of the external division is tenanted by small rounded cells, which confuse the fibrous character of the part. The laminae lie at an angle of 50° with the surface of the dentine, while the fibres of the outer part pass upwards at an angle of 25° , and finally turn outwards and advance to the surface at an angle of 90° .

Habrocoma Bennettii (WATERH.).—In the incisors of this creature, a few vascular canals are continued from the pulp-cavity for a short distance into the posterior half of the dentine. The dentinal tubes give off short branches from their commencement, undulate irregularly, and are not very uniform in size. They end without the presence of an anterior peripheral layer of cells. The confluent layers of enamel fibres leave the dentine at an angle of 50° , and have a thickness of about the 1666th of an inch. The fibres of the outer portion of this texture lie at an angle of 15° , the thickness of this part being about $\frac{2}{14}$ ths, while the lamelliform portion occupies $\frac{12}{14}$ ths of the whole thickness, which measures about the 108th of an inch in thickness: fig. 42 and 43 show the texture in a longitudinal and a transverse section. The molar teeth of this species of *Habrocoma* closely resemble those of *Schizodon fuscus*.

Chinchilla lanigera (MOLINA).—The dental tissues both of the molar and incisor teeth strongly resemble those of the four preceding species. In the incisor the dentine is without a peripheral layer of cells in the anterior half, and without vascular canals in the posterior half of the tooth. In a longitudinal section the confluent layers of enamel fibres have a thickness of about the 1500th of an inch, and leave the dentine

at an angle of 50° , which is diminished to 20° in the fibres of the outer portion of the tissue. In a transverse section, it is seen that the fibres in the outer part of the enamel are directed obliquely from the median line of the skull. The enamel fibres have a diameter of about the 6000th of an inch, and are intermingled in the lamelliform portion of the tissue with minute rounded or oval cells, which contribute to give the structure a confused appearance.

Cavia Aperea (ERXL).—A layer of obliquely placed cells occupies the periphery of the enamel-coated anterior of the incisors. The dentinal tubes have slightly irregular parietes, and the intervening tissue has a mottled cellular appearance. In the posterior half of the tooth, the tubes as they approach the periphery throw out numerous characteristic thick branches, which from their number and size render a section of this part very opaque.

The enamel is strongly Hystricine in character, and is dotted over with minute rounded and branchless cells*. In a longitudinal section of a lower incisor, the confluent laminæ leave the dentine at an angle of 45° , which is reduced to 20° in the fibres of the external part of the tissue, and the layers are about the 1500th of an inch thick: these characteristics are shown in fig. 44. The whole thickness of the enamel amounts to the 170th of an inch, of which two-thirds is occupied by the lamelliform portion of the tissue.

In the upper incisors the angle of 60° is that at which the lamellæ leave the surface of the dentine, while the terminal extremities of the fibres lie at an angle of 20° with the dentine. The enamel does not exceed the 212th of an inch in thickness, of which five-sevenths is lamelliform.

Cavia Kingii (BENNETT).—The dental tissues of this animal are very similar in structural character to those of the common Guinea Pig. The enamel is however less crowded with cells, and hence is much more transparent.

Hydrochaerus Capybara (ERXL).—Many vascular canals are continued from the pulp-cavity into the posterior half of the dentine in the incisor teeth of this great rodent. A few branches pass from the dentinal tubes throughout the whole of their course, and become more numerous near the periphery of the tissue, which in the anterior part of the tooth is bordered by a dense layer of irregular-shaped cells, that occupy a line the 500th of an inch thick, as shown in fig. 46.

The enamel exhibits the true Hystricine character, both in the longitudinal and transverse sections, but less strongly marked than in any of the previously described teeth belonging to animals of this group. The laminæ are more confluent, and the component fibres occupy a less oblique and more parallel position than we have been accustomed to see them; in a longitudinal section the enamel near the dentinal surface is crowded with small cells, and the laminæ are at this part indistinctly marked. A little farther out they become more strongly developed, and have the

* The cells in the enamel of this and in all the species described in this paper, have no proper parietes, and should be regarded as interspaces rather than cells in the sense now attached to that term.

appearance of being in pairs, the fibres of which proceed obliquely outwards from a central line common to the two, as shown in fig. 46. In the outer division of the tissue the component fibres are so intimately united, that in places only can their course be traced. In a longitudinal section the lamellæ leave the dentine at an angle of 70° , which is reduced to 30° in the outer part of this substance. The layers have a thickness of about the 700th of an inch, and the component fibres a diameter of the 7500th of an inch. The whole thickness of the enamel amounts to the 79th of an inch, of which $\frac{1}{9}$ ths is lamelliform.

In a transverse section of an upper incisor, the enamel fibres are seen to make one bold sigmoid curve in the lamelliform portion of the tissue. In fig. 45, a layer of fibres is shown with as much of the one immediately beneath as could be seen without shifting the focus of the instrument.

The enamel of the molar teeth exhibits much the same structural appearance as that of the incisors, excepting that the cells which occupy the inner part of the tissue in the latter teeth, are absent in these.

Brathyergus maritimus, GML. (Zoological Society).—This animal has been placed by Mr. WATERHOUSE in a section immediately preceding Hystricidæ*. The teeth are however Hystricine in structural character, and might be described either in this place or at the beginning of the family.

The dentine of the anterior parts of the tooth is bordered by a narrow layer of cells. The dentinal tubes have small hair-like branches through the whole of their course. In a longitudinal section of an upper incisor confluent layers of enamel fibres leave the surface of the dentine at an angle of 50° , and after extending about the 210th of an inch, are insensibly lost in the parallel arrangement of the fibres in the unusually thick external division of the tissue, which in this tooth amounts to the 120th of an inch in thickness, as shown in fig. 47. The tissue is dotted near the surface with minute cells. A transverse section is not altogether unlike a corresponding one from the incisor of the *Capybara*.

Pedetes Cafer (PALL.).—This animal is placed by Mr. WATERHOUSE in the family *Muridæ*, section *Dipodina*. The dental tissues of the incisor teeth have the Hystricine character strongly marked, while those of the molars are intermediate between the Hystricidæ and Leporidæ. The true position of the tissues in this family can only be determined after the majority of the species have been examined, which in itself will be a work of some labour, apart from the difficulty of obtaining authentic specimens. In the absence of correct information of its position, I have as a matter of convenience placed my description at the end of the Hystricine group.

In the incisors the dentine has several minor points of peculiarity. The pulp-cavity in a transverse section of a lower incisor approaches a triangular figure with the angles extended and rounded at their extremities, two of which are directed to the lateral anterior angles of the tooth, and the third extends in the median line into the

* Johnston's Physical Atlas.

posterior half, in addition to which the walls of the cavity have two deep indentations on the median side and one on the outer side of the tooth. From each of the angles a line of small vascular canals is continued a short distance into the dentine, which tissue is marked by numerous concentric and broad, but ill-defined and interrupted contour lines, which follow the involutions of the surface of the pulp-cavity. They seem to be produced by a greater density of the tissue in these than at other parts. The dentine has a generally diffused cellular appearance. The dentinal tubes have an irregular outline, and have small lateral branches throughout the whole of their course. When divided transversely they show thick and strongly-marked parietes, and have an internal diameter of about the 6000th and an external one of the 3000th of an inch. On nearing the enamel, the tubes give off larger and more numerous branches, and ultimately terminate in small oval or rounded branching cells.

In the upper incisors the vascular canals are more abundant in the posterior than in the anterior part of the tooth. The pulp-cavity is occupied near its apex with secondary dentine, the tubes of which proceed from the surface towards the centre and give off many branches; when viewed by transmitted light they resemble tufts of moss. The enamel is strongly Hystricine in character. In a longitudinal section of a lower incisor the confluent laminae leave the dentine at an angle of 60° , which in the external division of the tissue is reduced to 25° . The enamel has a thickness of the 79th of an inch, of which $\frac{1}{18}$ ths is lamelliform. The component fibres of the lamellae have a diameter of about the 7500th of an inch.

The dentinal tubes in the molar teeth proceed from the pulp-cavity in nearly a straight course upwards and outwards at an angle of 20° . When within the 500th of an inch of the enamel, they turn a little more outwards and afterwards a little upwards, thus describing a small final curve, the convexity of which is directed towards the base of the tooth. But few branches pass off till the dentinal tubes make their final curve, when many leave both their convex and concave sides. Vascular canals are continued from the pulp-cavity into the dentine, as in the incisor teeth. The arrangement of the component fibres of the enamel in the molars is peculiar, and probably characteristic of the tooth of this creature. In a longitudinal section the fibres in the first two-fifths or half of their curve are straight and parallel, and lie at an angle of 40° with the surface of the dentine. Afterwards they suddenly fall into the confluent lamelliform arrangement, and with this disposition reach the surface of the tooth, as shown in fig. 48. In the folds which lie between the confluent denticles, the enamel is thinner than on the exterior of the tooth; the loss of thickness is principally at the expense of the outer lamelliform portion. In a transverse section the fibres of the lamelliform portion are seen to make a open letter *f* curve, which is reversed in direction in the contiguous layers, but parallel, or nearly so, in the alternate ones. The appearances seen in this section are delineated in fig. 49. Both in the transverse and longitudinal sections the lamelliform portion of the enamel is crowded with small branchless cells.

The uniform presence and more constant breadth of the inner fibrous portion of the enamel is rather unusual in Hystricine teeth, while it is constant and exists in even a greater degree in the molars of the Hare. In this particular therefore the molars of the *Helamys* show a slight relation to those of the *Leporidæ*.

LEPORIDÆ.—In this family of rodents my observations have been confined to members of the genus *Lepus*. The incisors exhibit a type of enamel which I have seen in the teeth of no other rodents. This tissue is no longer divided into an outer and inner portion, with the component fibres arranged in lamellæ in one and not in the other, and at different angles in the two parts; but, on the contrary, the fibres without a lamelliform arrangement proceed with but slight flexures from the surface of the dentine to the outer surface of the enamel. Neither is the enamel dotted over with cells, as is that of Hystricine teeth in the lamelliform portion of the texture.

Lepus timidus (LINN.).—In the Hare the dentine is permeated by vascular canals, both in the anterior and posterior half of the incisors; but they are more numerous in the latter than in the former part. These canals become in the extruded portion of the tooth lined by a layer of dense non-tubular tissue, presenting the appearances delineated in fig. 51. The anterior enameled part of the incisors is bordered by a peripheral plexus of branches interspersed with a few branching cells, and the posterior half by a plexus of branches without cells. In a longitudinal section, such as that shown in fig. 50, the dentinal tubes from their commencement in all parts of the tooth branch, but in a transverse section the branches seem rather less numerous; hence it would appear that they extend principally in the long axis of the tooth. Prof. OWEN has observed that “the tubes which pass to the opposite or posterior surface of the tooth are less numerous, less parallel, and less closely packed together; they send out more and larger branches, which decussate each other in an elegant arborescent manner*.” In addition to these peculiarities, the tubes are sensibly larger in the lateral and posterior than in the anterior part of the tooth. In a longitudinal section, such as that shown in fig. 50, the enamel fibres may be traced through the whole thickness of the tissue. Generally their course is straight, or nearly so, and at an angle of from 50° to 70° with the surface of the dentine, but in places the angle is varied, and the fibres are a little bent in the one or other direction. The tissue is rendered rather unusually transparent by the close union of the component fibres, and its comparative freedom from small cells.

A corresponding section from an upper incisor differs from the one already described principally in the diminished thickness of the enamel. The enamel fibres have a diameter of about the 6800th of an inch.

The molar teeth of the Hare have dentine, which is traversed by vascular canals, that extend from the pulp-cavity to near the peripheral surface of the tissue. Previous to the part coming into wear the canals are lined with a non-tubular tissue, and ultimately become almost or quite obliterated. The dentinal tubes are sensibly larger,

* Odontography, page 405.

and branch much more freely than in the incisors: I do not know a more beautiful microscopic object than a fine longitudinal section of the molar tooth of a common Hare. The enamel, where it exists as a thin layer lining the inflected parts of the confluent denticles, is composed of short fibres, which leave the dentine at a wide angle, and towards their terminal extremities turn a little downwards. But when this tissue invests the outer and more exposed parts of the tooth the amount is much greater; in these parts the enamel is divisible into two portions, the inner of which is composed of straight, uniform and parallel fibres, and the outer part of continuations of the same fibres, but bent about somewhat irregularly, and approaching in places to a confluent lamelliform arrangement. The appearances presented in a transverse section of a molar tooth are delineated in fig. 52; but even in this the arrangement of the enamel fibres in the outer portion of the tissue is regular as compared with what is seen in many parts of the tooth. In the outer part the fibres have the appearance of being smaller than those which lie next the dentine, as shown in the figure.

Lepus cuniculus (LINN.).—The dental tissues in the teeth of the Rabbit so closely resemble those of the Hare, that I doubt the possibility of telling the one from the other, excepting by the external form and size of the entire tooth. The vascular canals are perhaps less numerous in the Rabbit.

Of the following animals I have been able to obtain the molar teeth only.

Lepus Americanus, ERXL. (Zoological Society).—The vascular canals are very numerous and extend to within a short distance of the enamel, where they usually terminate in dilated extremities. In their passage they branch rectangularly and anastomose with neighbouring canals, a circumstance I have not before observed in the vessels of vascular dentine. Each canal becomes surrounded by a layer of transparent tissue, in which are a few lacunæ very similar to those seen in the cement; eventually the canals are lost by the encroaching inwards of the transparent tissue, and lines of branching cells alone remain to mark their former position.

The enamel could not be readily distinguished from that seen in the molars of *Lepus timidus*; a tendency to confluent lamelliform arrangement of the fibres is found in places, and as it appears in a longitudinal section is shown in fig. 53.

In the molar teeth of *Lepus aquaticus* (BACHM.) and *Lepus sylvaticus* (BACHM.), I find no characteristic differences in the dental tissue by which they could be distinguished from each other, or from the teeth of either of the preceding species of Hares.

Before leaving the subject of Hares' teeth, I should state that occasionally fine supplemental enamel fibres may be seen crossing the course of the ordinary ones at a right angle. They do not exceed the 15,000th of an inch in diameter, and are not constantly present; indeed I have only seen them near the basal half of the tooth, where the enamel is not perfectly hardened.

The facts which are recorded in the foregoing pages have been gathered from
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careful and repeated observations made upon upwards of 350 sections, cut from the teeth of various members of the order Rodentia. When a doubt as to the nature of a tissue has arisen, I have made numerous sections from different parts, and in different directions of the same tooth. In some instances I have made as many as twenty-five from the teeth of one species; and have seldom contented myself with less than three sections.

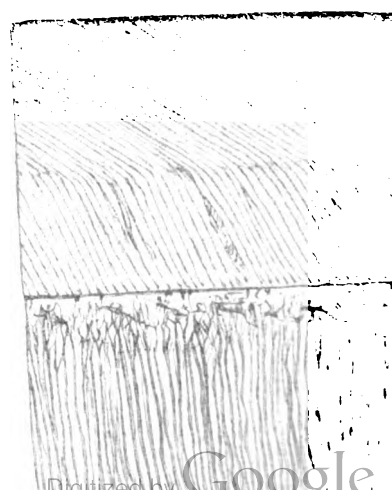
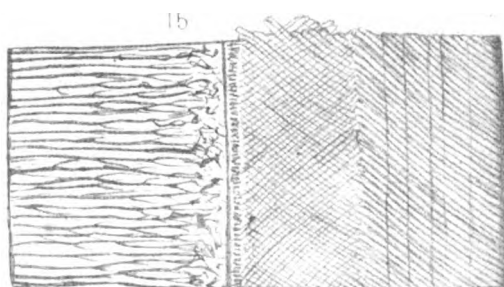
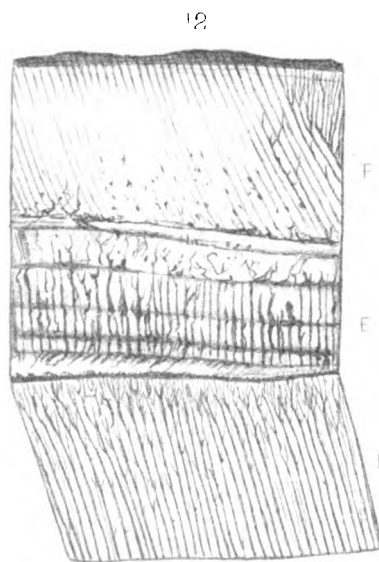
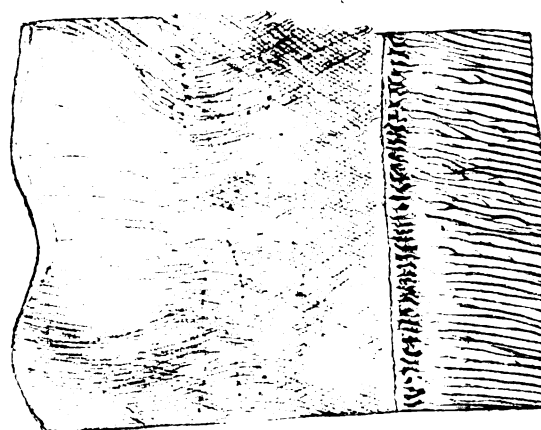
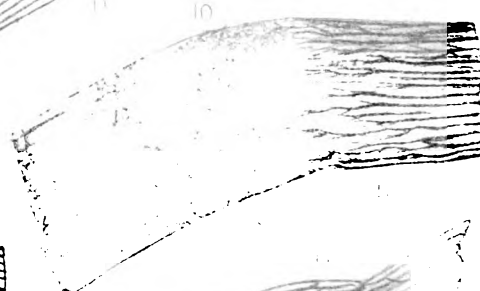
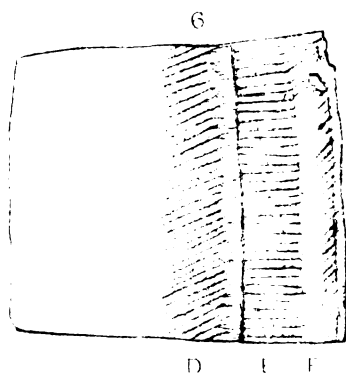
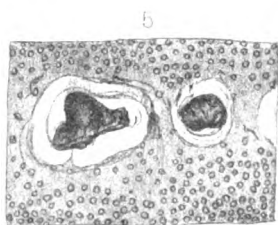
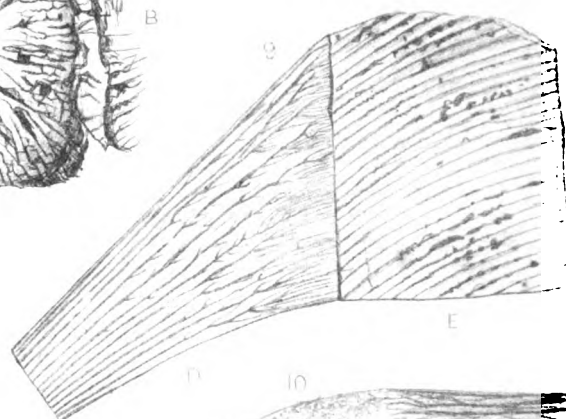
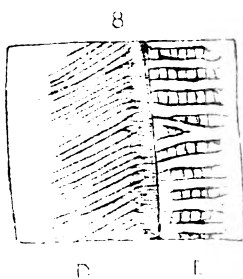
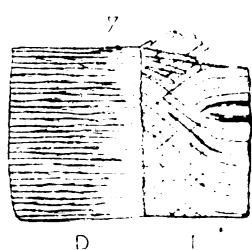
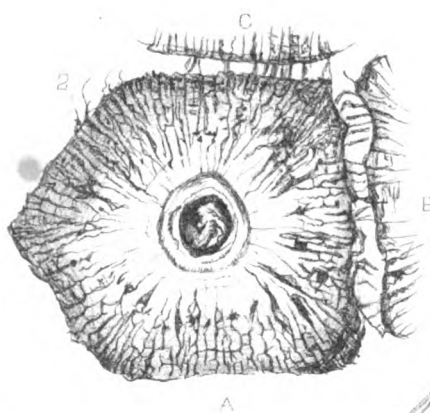
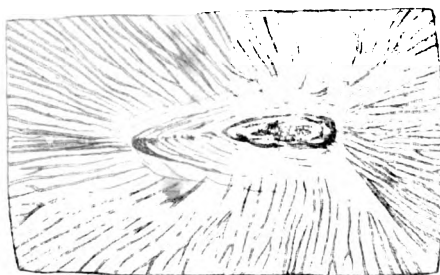
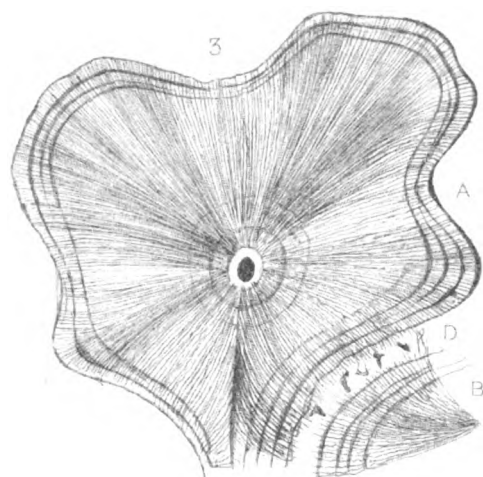
The conclusions which these researches justify depend mainly on the accuracy with which the observations have been made and recorded.

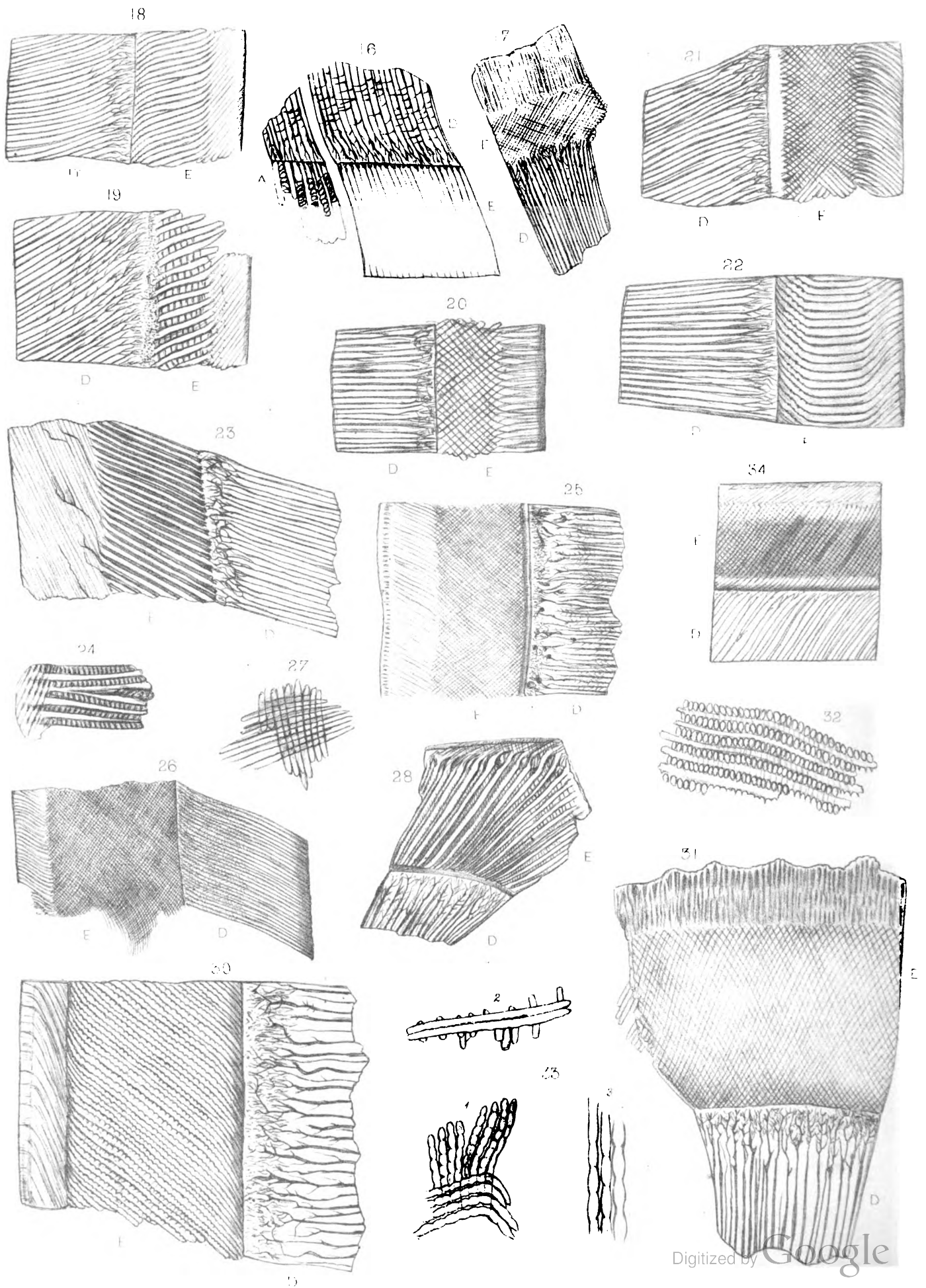
Fortunately, preparations of dental tissues can be preserved for an unlimited period: hence my statements can at any time be tested by an examination of my own or corresponding sections.

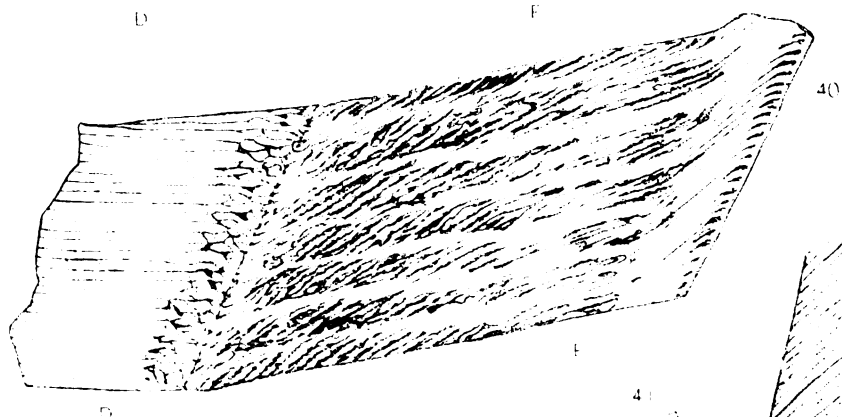
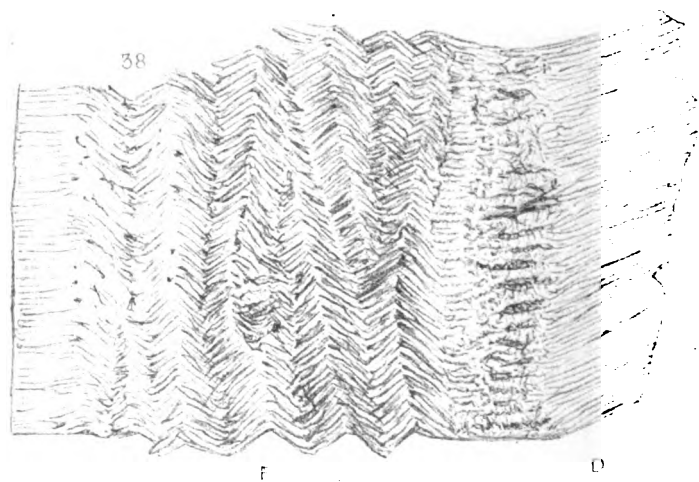
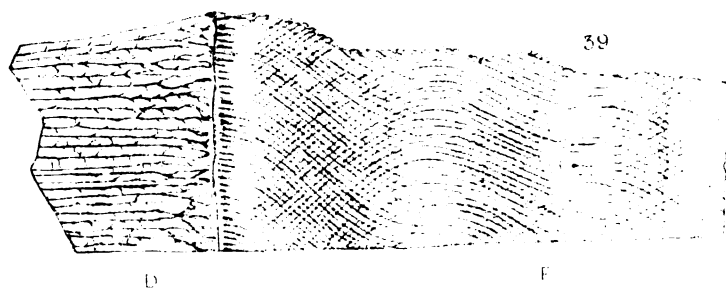
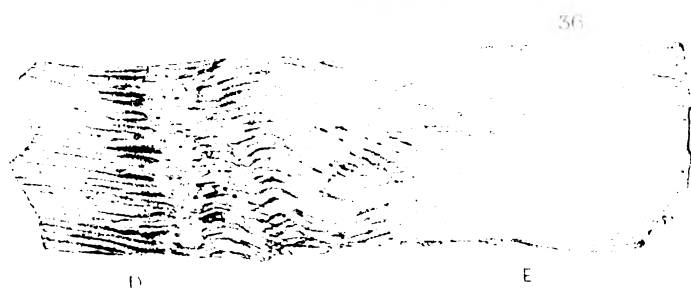
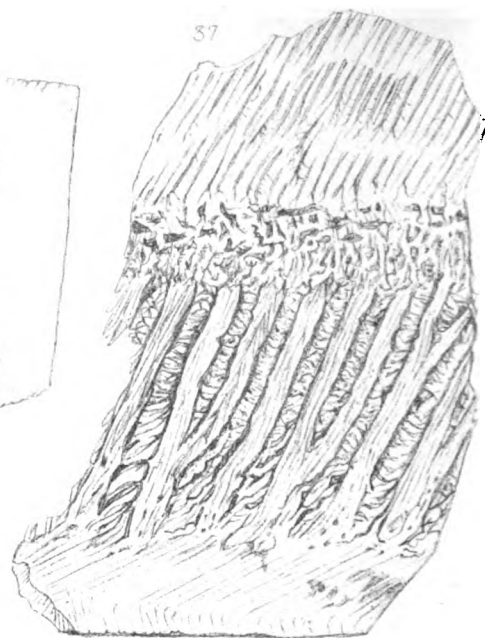
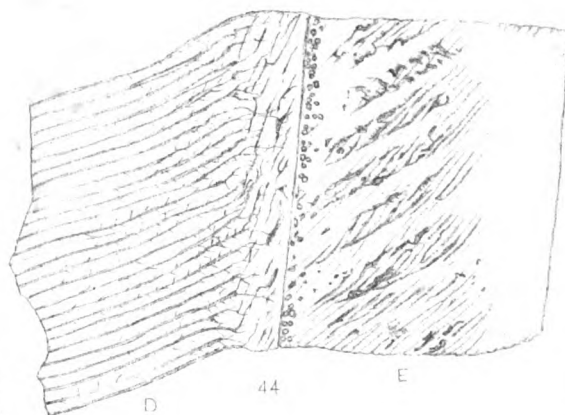
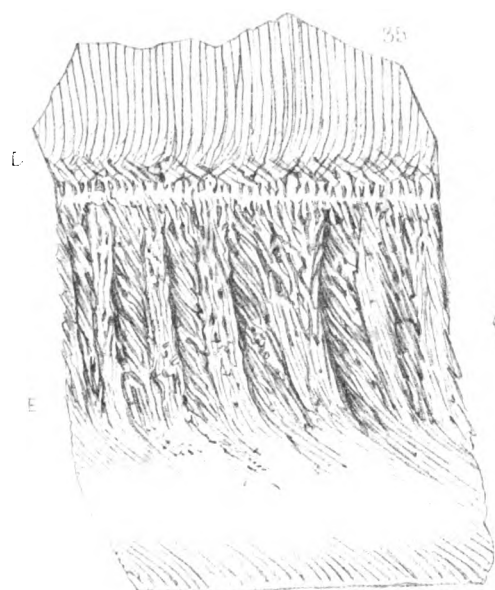
Those who will go over the field of observation through which I have passed, will I do not doubt justify me in the following conclusions:—viz. That the teeth of some species of the order have specific structural characters by which they can be distinguished from any other known teeth. That in the teeth of all the Rodentia, excepting the family Leporidæ, a portion of the enamel has a lamelliform arrangement of its fibres. That the enamel lamellæ have a different and distinctive character in each of the larger groups, and that the variety of structure is constant throughout the members of the same group; we may take for examples, the Sciuridæ, the Muridæ, and Hystricidæ, in each of which the structure of the enamel is different, and in each is highly distinctive. And that the varieties in the structure of the dental tissues, with a few isolated exceptions, justify and accord with the arrangements of the members of the order into the several divisions proposed by Mr. WATERHOUSE, and deduced by him from the relations of the several parts of the skull.

The manner in which these various modifications in the structure of the enamel are brought about in its development, together with the adaptation of the varied forms of enamel-tissue to the wants of its possessors, will form the subjects of a future communication.

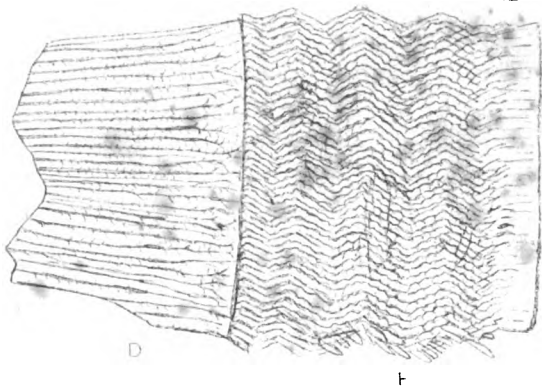
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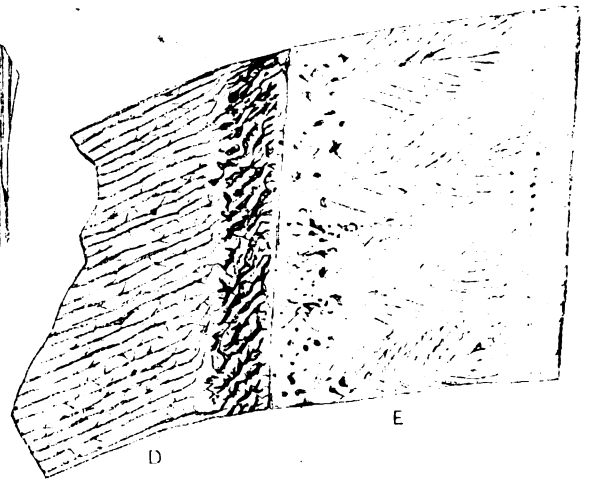
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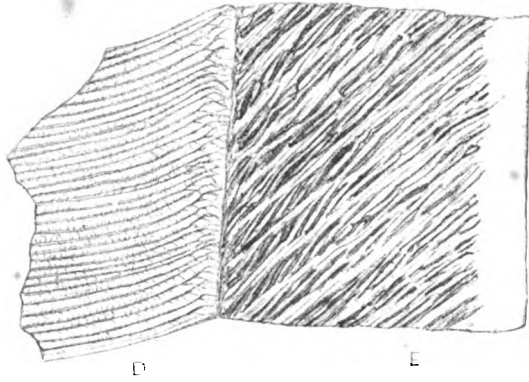
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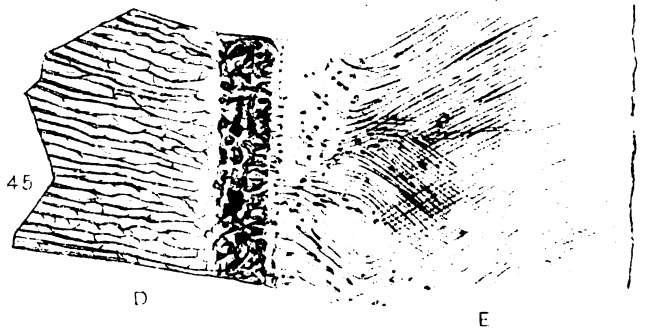
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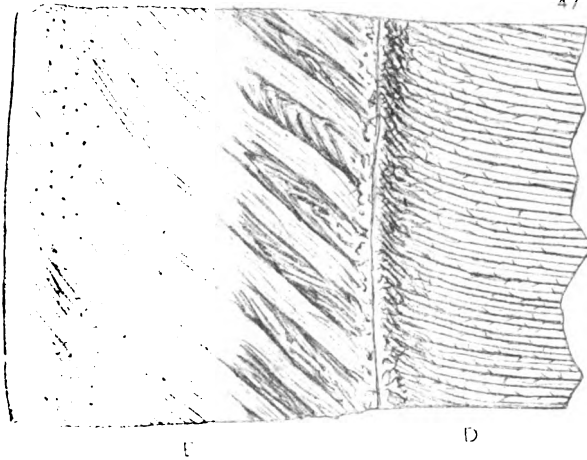
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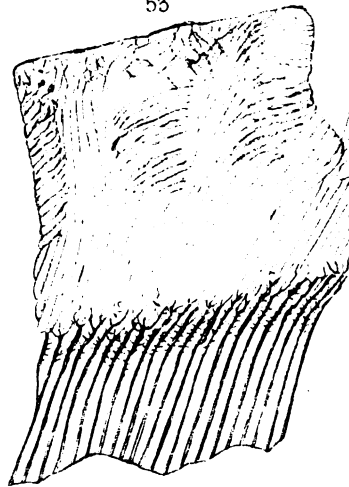
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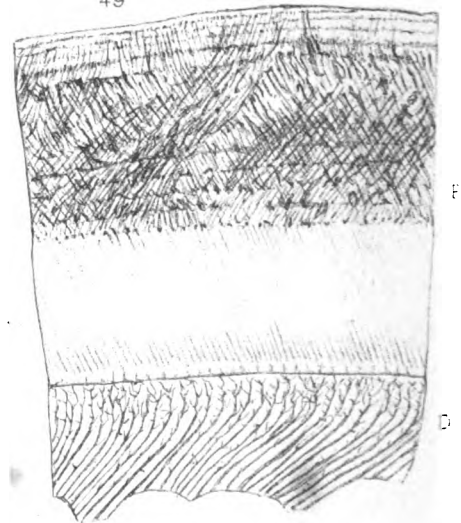
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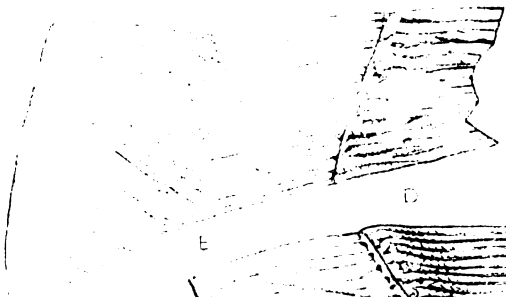
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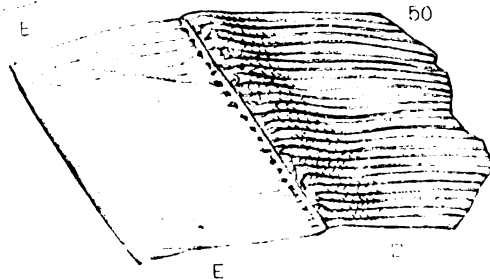
49



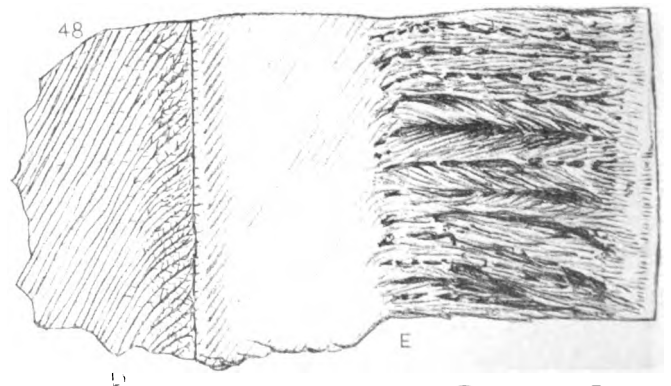
52



50



48



EXPLANATION OF THE FIGURES, in each of which D refers to the dentine,
and E to the enamel.

PLATE XLIII.

- Fig. 1. The middle portion of a transverse section of the lower incisor of *Tamias Lysteri*, showing the manner in which the dentinal tubes are disconnected from the pulp-cavity in that part of the tooth which is about to come into wear by the development of a laminated subgranular tissue. 150 linear.
- Fig. 2. A transverse section of a dentinal system, A, and peripheral portion of two contiguous ones, B and C, from the tooth of *Orycteropus*, showing the manner in which the connection of the dentinal tubes with the surface of the pulp-cavity is cut off by the development of a laminated mass of transparent and apparently structureless tissue.
- Fig. 3. A transverse section of a dentinal system, A, and a portion of a contiguous one, B, from the tooth of *Labyrinthodon Jaegeri*, showing the disconnection of the tubes with the pulp-cavity in A, and the process, C, by which this is connected with a contiguous system; also the peripheral line of cells which intervene and partially connect the terminal branches of the tubes of adjoining systems. (This drawing was made from a section, No. 4 of a series lent to me by Dr. MANTELL.) 75 linear.
- Fig. 4. A transverse section of a Haversian system from a Stag's antler which had been cast, showing the transparent tissue lining the canal, and thus cutting off the connection of the canaliculi with the surface of the canal.
- Fig. 5. A transverse section from the extruded portion of a molar tooth of *Lepus timidus*, showing that the medullary canals of vascular dentine become lined with a dense non-tubular tissue previous to the part coming into wear.
- Fig. 6. A portion of a longitudinal section from an upper incisor of *Sciurus niger*, showing, D, the dentine, E, the enamel lamellæ in their rectangular position, and F, the terminal or fibrous part of the enamel, in which the extent of the colour is marked by a vertical line. 225 linear.
- Fig. 7. A transverse section of the same tooth, showing, D, the dentine, and E, the enamel, in which the component fibres of two layers, the decussation and their continuance in the external part of the tissue, are seen. 225 linear.
- Fig. 8. An oblique longitudinal section from the base of the same tooth, in which E, the alternate layers of the enamel lamellæ, are cut transversely and longitudinally. In this part of the tooth the external part of the enamel is not fully developed.

- Fig. 9. A portion of a longitudinal section from the crown of a molar tooth of *Sciurus niger*, showing, D, the dentine, and E, the enamel, with the fibres interspersed with irregular cells.
- Fig. 10. A longitudinal section from the fang of the same tooth, showing, D, the dentine, and C, the cementum, in the outer portion of which the tissue is arranged in rods, and is free from lacunæ.
- Fig. 11. A portion of a longitudinal section from the crown of a molar tooth of *Sciurus erythropus*, showing, D, a part of the dentine with the tubes combined into E, a portion of the enamel.
- Fig. 12. A portion of a longitudinal section of an upper incisor of *Arctomys pruinosis*, showing, D, the dentine, E, the enamel, with the lamellæ leaving the surface of the dentine at a right angle, and F, the outer fibrous division of the enamel. 150 linear.
- Fig. 13. A transverse section from the same tooth, showing, D, the dentine, and E, the enamel.
- Fig. 14. A portion of a longitudinal section from the upper incisor of *Castor fiber*, showing, D, the dentine with a peripheral layer of cells, E, the lamelliform portion, and F, the outer fibrous portion of the enamel.
- Fig. 15. A transverse section from the same tooth, showing, D, the dentine, E, the enamel, with the decussation of the component fibres of two laminæ, and F, the outer part of the enamel.

PLATE XLIV.

- Fig. 16. A portion of a longitudinal section from an upper incisor of *Spalax typhlus*, showing a peripheral portion of dentine with the downward direction of the branches of the dentinal tubes, and E, the enamel; A, an oblique longitudinal section, showing the fibres of alternate laminæ divided transversely. 150 linear.
- Fig. 17. A transverse section from the same tooth; D, the dentine, E, the enamel. 150 linear.
- Fig. 18. A longitudinal section from an upper incisor of a Dormouse (*Myoxus avelanarius*); D, peripheral portion of dentine, E, the enamel, showing the curved enamel lamellæ and the fibres in the outer part of the tissue. 300 linear.
- Fig. 19. An oblique longitudinal section from the same tooth, showing at E alternate layers of enamel fibres divided transversely with the intermediate ones exposed in their length. 300 linear.
- Fig. 20. A transverse section of the same tooth. 300 linear.

- Fig. 21. A longitudinal section of a lower incisor of *Myoxus avellanarius*, showing at E the decussation of the parallel layers of enamel fibres, and the downward direction of the external ends.
- Fig. 22. A transverse section of the same tooth, showing the outward course of the enamel lamellæ, their serrated margins near the dentine, and their vertical position.
- Fig. 23. A vertical section from the upper incisor of a Jerboa (*Dipus Ægyptius*), showing, D, the dentine at its anterior peripheral surface, and E, the enamel with a few tubes continued into the outer part. 150 linear.
- Fig. 24. An oblique longitudinal section, showing enamel fibres divided transversely and longitudinally. 300 linear.
- Fig. 25. A transverse section of an upper incisor of the Jerboa, showing, D, the dentine, and E, the enamel, with the decussation of the fibres of contiguous layers in the lamelliform portion of the tissue, and their parallel course in the outer part of the enamel. 150 linear.
- Fig. 26. A longitudinal section of a lower incisor of the Jerboa from near the base of the tooth, showing, D, the dentine, and E, the enamel, with the lamellæ arranged in the length of the tooth. 150 linear.
- Fig. 27. Enamel fibres scraped from the partially calcified tissue near the base of the tooth. 600 linear.
- Fig. 28. A transverse section of a lower incisor of the Jerboa, showing the enamel lamellæ divided transversely with the fibres of alternate layers cut obliquely, and the intervening one longitudinally.
- Fig. 29. Plate XLV. A longitudinal section of a molar of the Jerboa, showing the periphery of the dentine and the dentinal tubes continued into the enamel, with the manner of termination of the tubes in the latter texture.
- Fig. 30. A longitudinal section of a lower incisor of a Rat (*Mus decumanus*), showing, D, the terminal portion of the dentine, and E, the enamel, with its serrated lamellæ and its outer fibrous portion. 300 linear.
- Fig. 31. An oblique transverse section from the same tooth, showing the crossing of the fibres of contiguous layers, and the pattern thus produced. 300 linear.
- Fig. 32. A section from the same tooth, in which the fibres of alternate layers are divided transversely, and the intermediate ones exposed in their length, and show minute denticulations.
- Fig. 33. Enamel fibres in various stages of development, obtained from the partially calcified tissue about the base of the incisor.
- Fig. 34. A longitudinal section from a lower incisor of the Bank Vole (*Arvicola glareolus*), showing at E the denticulated character of the enamel lamellæ and their transverse markings.

PLATE XLV.

- Fig. 35. A longitudinal section of the upper incisor of the Porcupine (*Hystrix cristata*), in which is shown, D, the terminal portion of the dentine with its obliquely placed elongated cells, and E, the enamel with its confluent layers of obliquely placed fibres and the parallel fibres of the outer portion of the tissue. 120 linear.
- Fig. 36. A transverse section from the same tooth, showing, D, the dentine, and E, the enamel fibres pursuing a serpentine course in the lamelliform part of the tissue, and a straight parallel course in the external division of the tissue. 120 linear.
- Fig. 37. An oblique longitudinal section from a lower incisor of the Spotted Cavy (*Cælogenys Paca*), showing, D, the dentine with its peripheral layer of cells, and E, the enamel with the confluent layers, and with the fibres of alternate ones divided more or less transversely.
- Fig. 38. An oblique transverse section from the same tooth, showing, D, the dentine, and E, the enamel with the fibres in their waved course in the lamelliform portion, and parallel course in the outer portion of the tissue.
- Fig. 39. An oblique transverse section from a lower incisor of *Capromys Fournieri*, showing, D, the dentine, and E, the enamel, which in this figure is rather a diagram illustrating the arrangement of the enamel fibres, than a faithful delineation of the appearance presented in the section.
- Fig. 40. A longitudinal section from the same tooth, showing, D, the dentine, and E, the enamel, with its confluent laminae and the oblique constituent fibres.
- Fig. 41. An oblique transverse section from the same tooth, showing at E the appearance assumed by the enamel laminae near the sides of the tooth when the fibres are exposed in their length in the middle part of the section.

PLATE XLVI.

- Fig. 42. An oblique transverse section from the upper incisor of *Habrocoma Bennettii*, showing, D, the dentine, and E, the enamel, with the direction of the enamel fibres.
- Fig. 43. A longitudinal section from the upper incisor of *Habrocoma Bennettii*, showing, D, the dentine, and E, the enamel with its confluent laminae. 150 linear.
- Fig. 44. Plate XLV. A longitudinal section from a lower incisor of the Guinea Pig (*Cavia Aperea*), showing, D, the peripheral portion of the dentine with its terminal layer of oblique elongated cells, and E, the enamel and its confluent laminae. 200 linear.

- Fig. 45. A transverse section from an upper incisor of the Capybara (*Hydrochærus Capybara*), showing, D, the dentine, and E, the enamel. 150 linear.
- Fig. 46. A longitudinal section from the same tooth, showing the peripheral layer of cells, D, and E, the enamel with the penniform character of the confluent lamellæ. 150 linear.
- Fig. 47. A longitudinal section from an upper incisor of *Brathyergus maritimus*, showing, D, the dentine, and E, the enamel with its peculiar Hystricine enamel laminæ, and the large amount of the external division of the tissue. 150 linear.
- Fig. 48. A longitudinal section of a molar of *Pedetes Cafer*, showing, D, the dentine, and E, the enamel, with the inner portion fibrous, and the outer lamelli-form.
- Fig. 49. A transverse section from the same tooth ; D, the dentine, and E, the enamel.
- Fig. 50. A longitudinal section from a lower incisor of the Hare (*Lepus timidus*), showing, D, the dentine, and E, the enamel fibres, without a lamelli-form arrangement, and without a division into an external and internal portion. 200 linear.
- Fig. 51. A vascular canal surrounded by a layer of non-tubular tissue, as seen in a longitudinal section of an incisor of the Hare. 300 linear.
- Fig. 52. A transverse section from a molar of the Hare (*Lepus timidus*), showing, D, the dentine with its large tubes, and E, the enamel with the fibres in the inner portion parallel, and in the outer curved and irregularly Hystricine. 200 linear.
- Fig. 53. A longitudinal section from a molar of *Lepus Americanus*, showing the irregular lamelliform character of the outer portion of the enamel. 200 linear.

XXIX. *Sequel to a paper on the Reduction of the Thermometrical Observations made at the Apartments of the Royal Society. By JAMES GLAISHER, Esq., F.R.S., of the Royal Observatory, Greenwich.*

Received December 14, 1849,—Read February 28, 1850.

IN a paper which the Royal Society did me the honour to publish in the last volume of its Transactions, I gave the results found from all the thermometrical observations which have been taken at the Apartments of this Society; and I stated that I had made some progress in the connection of this series of results with those deduced from the observations at the Royal Observatory, Greenwich. Since that time I have reduced the two series of observations to one and the same series, and I have now the honour to lay the results from their combination before the Society.

In my former paper I stated that no observations had been taken between the years 1781 and 1786. Had the particulars of these years been about their average values, their omission would not have materially affected the final results, but on examination I found that those years were distinguished by very severe weather, and that their omission would have a sensible effect; I have therefore supplied these particulars, as detailed below.

I also stated that it was doubtful whether the temperatures, as determined for Somerset House, were influenced by local causes. I have endeavoured to collect information upon this subject, and of which I shall speak presently.

I shall adopt the same plan in the arrangement of the final results, which I pursued in my former paper, and present them for monthly, quarterly and yearly periods. The numbering of the Tables is continued from the former paper. It may tend to clearness if I speak of each preliminary investigation separately.

Determination of the Mean Temperature of the Air at Lyndon in Rutlandshire, the longitude of which place is 0° 3' East of Greenwich and the latitude is 52° 32' North, for every month in the years from 1771 to 1799.

The results of meteorological observations taken by THOMAS BARKER, Esq., at Lyndon in Rutlandshire, and which seems to have been taken with care, were published in the volumes of the Philosophical Transactions for the years 1772 to 1799. From these papers I have determined the mean monthly temperatures of the air, and which are shown in the following Table:—

TABLE VIII.—Mean monthly temperature of the Air at Lyndon in Rutlandshire, from the year 1771 to the year 1798.

Year.	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	December.
1771.	30·5	34·0	35·0	40·0	56·2	56·6	61·5	59·7	52·7	47·5	41·2	41·2
1772.	32·8	34·8	38·8	43·5	50·3	62·0	62·0	61·0	55·7	52·7	43·7	39·3
1773.	37·5	35·5	41·2	45·5	49·2	58·2	60·5	62·2	54·5	48·5	39·5	38·0
1774.	31·2	37·8	41·0	46·5	51·5	60·2	61·0	61·2	54·2	48·2	39·0	35·8
1775.	38·7	42·5	41·5	49·7	55·0	62·7	64·0	59·7	57·8	47·5	37·8	37·5
1776.	27·5	38·2	43·2	47·8	52·0	59·2	63·8	60·0	55·2	49·8	41·2	38·8
1777.	33·5	34·2	43·2	45·0	54·0	57·7	61·5	61·5	57·7	49·8	42·7	35·2
1778.	34·5	35·8	40·0	46·0	55·5	62·2	66·0	62·5	52·2	44·8	43·2	42·0
1779.	36·0	44·5	44·2	49·2	54·0	58·2	65·5	65·0	59·0	50·8	40·8	36·7
1780.	29·5	35·0	45·5	43·0	55·8	58·8	63·5	64·0	58·5	48·5	38·0	36·7
1781.	34·0	40·7	43·0	48·5	53·2	63·5	64·5	64·0	57·5	48·8	42·0	40·8
1782.	39·5	35·0	39·0	42·0	49·8	60·5	61·2	58·0	56·2	45·5	35·0	36·0
1783.	37·5	39·8	38·0	49·2	50·0	61·0	67·7	62·0	55·3	49·3	42·8	34·8
1784.	29·8	32·5	36·5	43·3	58·5	58·8	61·5	57·5	58·0	44·2	41·0	30·8
1785.	36·7	31·0	34·2	47·5	54·2	62·0	64·2	58·8	57·5	47·2	40·5	35·0
1786.	36·5	36·8	34·5	46·0	54·0	62·2	61·0	60·2	52·0	45·0	37·0	Ther. broken.
1787.	37·2	42·5	44·2	46·0	53·8	60·0	62·5	61·8	59·0	50·2	38·8	39·0
1788.	38·5	39·0	39·0	50·8	59·3	61·5	65·5	62·0	57·5	50·2	42·0	34·2
1789.	34·5	40·5	36·0	47·0	56·8	60·0	63·0	63·0	56·8	48·0	39·8	42·0
1790.	39·0	42·8	44·8	43·8	55·2	61·5	63·0	62·5	55·2	50·2	42·2	40·8
1791.	.....	39·8	43·2	50·5	52·0	59·8	61·5	63·0	58·0	47·8	42·2	33·0
1792.	36·5	38·8	43·2	51·5	52·2	57·8	62·5	64·2	54·0	48·8	44·8	40·2
1793.	36·5	40·5	40·2	43·0	53·2	60·0	68·2	62·5	55·0	53·8	43·2	41·0
1794.	34·5	45·5	45·2	52·0	53·5	62·5	69·0	61·8	54·8	49·5	43·5	37·2
1795.	26·8	32·8	39·8	46·8	54·5	58·0	60·2	64·5	61·8	54·0	41·0	44·5
1796.	44·8	40·5	40·5	51·2	51·0	60·5	62·5	62·5	60·0	47·2	40·5	32·0
1797.	38·0	38·2	40·0	45·8	55·0	57·8	66·8	63·0	55·0	48·0	41·2	40·2
1798.	38·5	38·8	41·2	51·5	56·8	65·8	64·5	64·2	58·5	51·0	40·5	33·2

During twenty of these years simultaneous observations were taken at the Apartments of this Society. The following Table of comparison of results is formed by comparing the numbers in the preceding Table with those for the same months in Table I. of my paper in the Philosophical Transactions, Part II., 1849.

TABLE IX.—Comparison of the mean monthly temperature of the Air at the Apartments of the Royal Society, with the mean monthly temperature of the Air at Lyndon.

Years.	January.			February.			March.			April.			May.			June.		
	Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.		
	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.
1774.	33.1	31.2	+1.9	39.4	37.8	+1.6	43.9	41.0	+2.9	47.9	46.5	+1.4	53.2	51.5	+1.7	61.0	60.2	+0.8
1775.	42.0	38.7	+3.3	43.3	42.5	+0.8	42.8	41.5	+1.3	50.8	49.7	+1.1	55.2	55.0	+0.2	63.5	62.7	+0.8
1776.	28.6	27.5	+1.1	41.4	38.2	+3.2	44.8	43.2	+1.6	48.3	47.8	+0.5	51.7	52.0	-0.3	59.6	59.2	+0.4
1777.	35.5	33.5	+2.0	37.2	34.2	+3.0	45.7	43.2	+2.5	45.1	45.0	+0.1	53.4	54.0	-0.6	57.2	57.7	-0.5
1778.	36.4	34.5	+1.9	37.0	35.8	+1.2	41.2	40.0	+1.2	48.0	46.0	+2.0	55.9	55.5	+0.4	62.2	62.2	0.0
1779.	36.4	36.0	+0.4	46.7	44.5	+2.2	48.1	44.2	+3.9	51.8	49.2	+2.6	55.8	54.0	+1.8	58.9	58.2	+0.7
1780.	30.2	29.5	+0.7	36.7	35.0	+1.7	50.3	45.5	+4.8	44.7	43.0	+1.7	57.2	55.8	+1.4	60.0	58.8	+1.2
1781.	37.8	34.0	+3.8	41.7	40.7	+1.0	43.7	43.0	+0.7	47.2	48.5	-1.3	54.2	53.2	+1.0	63.4	63.5	-0.1
1787.	38.3	37.2	+1.1	40.9	42.5	-1.6	43.9	44.2	-0.3	45.5	46.0	-0.5	52.4	53.8	-1.4	58.7	60.0	-1.3
1788.	39.0	38.5	+0.5	40.1	39.0	+1.1	39.7	39.0	+0.7	50.6	50.8	-0.2	57.4	59.3	-1.9	59.5	61.5	-2.0
1789.	35.0	34.5	+0.5	41.3	40.5	+0.8	35.5	36.0	-0.5	45.2	47.0	-1.8	54.3	56.8	-2.5	55.7	60.0	-4.3
1790.	40.2	39.0	+1.2	42.6	42.8	-0.2	44.3	44.8	-0.5	42.0	43.8	-1.8	53.7	55.2	-1.5	57.7	61.5	-3.8
1791.	41.4	No obs.	.....	40.2	39.8	+0.4	43.2	43.2	0.0	49.9	50.5	-0.6	50.5	52.0	-1.5	58.5	59.8	-1.3
1792.	36.5	36.5	0.0	38.8	38.8	0.0	43.2	43.2	0.0	50.0	51.5	-1.5	50.7	52.2	-1.5	55.2	57.8	-2.6
1793.	36.9	36.5	+0.4	41.1	40.5	+0.6	40.4	40.2	+0.2	43.5	43.0	+0.5	51.8	53.2	-1.4	56.3	60.0	-3.7
1794.	34.9	34.5	+0.4	46.1	45.5	+0.6	45.4	45.2	+0.2	50.7	52.0	-1.3	51.7	53.5	-1.8	58.5	62.5	-4.0
1795.	25.5	26.8	-1.3	35.5	32.8	+2.7	39.7	39.8	-0.1	46.2	46.8	-0.6	53.0	54.5	-1.5	54.6	58.0	-3.4
1796.	46.9	44.8	+2.1	41.0	40.5	+0.5	40.1	40.5	-0.4	49.4	51.2	-1.8	51.2	51.0	+0.2	57.0	60.5	-3.5
1797.	37.0	38.0	-1.0	37.0	38.2	-1.2	39.0	40.0	-1.0	45.8	45.8	0.0	52.4	55.0	-2.6	57.7	57.8	-0.1
1798.	39.4	38.5	+0.9	39.3	38.8	+0.5	41.8	41.2	+0.6	50.3	51.5	-1.2	54.7	56.8	-2.1	62.1	65.8	-3.7
	July.			August.			September.			October.			November.			December.		
	Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.		
	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.	Somerset House.	Lyndon.	Higher at Somerset House.
1774.	62.8	61.0	+1.8	61.5	61.2	+0.3	55.8	54.2	+1.6	50.1	48.2	+1.9	40.5	39.0	+1.5	38.5	35.8	+2.7
1775.	64.0	64.0	0.0	62.1	59.7	+2.4	59.5	57.8	+1.7	49.5	47.5	+2.0	41.5	37.8	+3.7	40.7	37.5	+3.2
1776.	63.8	63.8	0.0	63.0	60.0	+3.0	55.6	55.2	+0.4	52.8	49.8	+3.0	44.0	41.2	+2.8	41.5	38.8	+2.7
1777.	61.5	61.5	0.0	63.7	61.5	+2.2	59.2	57.7	+1.5	52.6	49.8	+2.8	45.0	42.7	+2.3	37.2	35.2	+2.0
1778.	68.0	66.0	+2.0	64.8	62.5	+2.3	54.5	52.2	+2.3	47.3	44.8	+2.5	46.0	43.2	+2.8	44.2	42.0	+2.2
1779.	65.9	65.5	+0.4	65.2	65.0	+0.2	61.8	59.0	+2.8	53.2	50.8	+2.4	43.2	40.8	+2.4	41.6	36.7	+4.9
1780.	64.2	63.5	+0.7	67.0	64.0	+3.0	60.4	58.5	+1.9	51.3	48.5	+2.8	40.8	38.0	+2.8	38.0	36.7	+1.3
1781.	66.3	64.5	+1.8	64.3	64.0	+0.3	55.5	59.0	-3.5	49.9	50.2	-0.3	40.9	38.8	+2.1	41.0	39.0	+2.0
1787.	62.4	62.5	-0.1	62.4	61.8	+0.6	55.5	59.0	-3.5	49.9	50.2	-0.3	40.9	38.8	+2.1	41.0	39.0	+2.0
1788.	61.6	65.5	-3.9	61.2	62.0	-0.8	57.0	57.5	-0.5	50.4	50.2	+0.2	41.9	42.0	-0.1	30.4	34.2	-3.8
1789.	59.8	63.0	-3.2	61.5	63.0	-1.5	55.7	56.8	-1.1	48.1	48.0	+0.1	40.0	39.8	+0.2	43.0	42.0	+1.0
1790.	60.1	63.0	-2.9	61.2	62.5	-1.3	55.0	55.2	-0.2	50.8	50.2	+0.6	43.3	42.2	+1.1	40.4	40.8	-0.4
1791.	60.5	61.5	-1.0	63.7	63.0	+0.7	57.9	58.0	-0.1	47.9	47.8	+0.1	42.6	42.2	+0.4	36.2	33.0	+3.2
1792.	59.6	62.5	-2.9	63.5	64.2	-0.7	56.5	54.0	+2.5	50.0	48.8	+1.2	44.5	44.8	-0.3	41.4	40.2	+1.2
1793.	65.9	68.2	-2.3	60.3	62.5	-2.2	53.9	55.0	-1.1	53.2	53.8	-0.6	44.2	43.5	+0.7	42.4	41.0	+1.4
1794.	66.3	69.0	-2.7	60.7	61.8	-1.1	54.8	54.8	0.0	49.6	49.5	+0.1	44.6	43.5	+1.1	38.2	37.2	+1.0
1795.	59.9	60.2	-0.3	62.1	64.5	-2.4	61.9	61.8	+0.1	54.7	54.0	+0.7	42.0	41.0	+1.0	46.2	44.5	+1.7
1796.	59.6	62.5	-2.9	61.2	62.5	-1.3	60.2	60.0	+0.2	47.8	47.2	+0.6	41.6	40.5	+1.1	31.8	39.0	-7.2
1797.	64.3	66.8	-2.5	60.3	63.0	-2.7	55.7	55.0	+0.7	48.3	48.0	+0.3	42.7	41.2	+1.5	42.6	40.2	+2.4
1798.	62.2	64.5	-2.3	62.8	64.2	-1.4	57.6	58.5	-0.9	51.1	51.0	+0.1	41.3	40.5	+0.8	35.1	33.2	+1.9

By taking the means of the differences of the results, we find that the reading of the thermometer in air at the Apartments of the Royal Society in

January was higher than at Lyndon by	1.0
February was higher than at Lyndon by	0.8
March was higher than at Lyndon by	0.8
April was lower than at Lyndon by	0.2
May was lower than at Lyndon by	0.6
June was lower than at Lyndon by	1.7
July was lower than at Lyndon by	1.0
August was higher than at Lyndon by less than .	0.1
September was higher than at Lyndon by . . .	0.4
October was higher than at Lyndon by	1.0
November was higher than at Lyndon by . . .	1.0
December was higher than at Lyndon by . . .	1.6

Determination of the Mean Temperature of each month at the Apartments of the Royal Society for those months when no observations were made there.

By applying the above numbers to those in Table VIII. when no observations were taken at the Apartments of the Royal Society, the following Table is formed :—

TABLE X.—Showing the approximate mean monthly temperature of the Air at the Apartments of the Royal Society.

Year.	Approximate mean temperature of the air.											
	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
1771.	31.5	34.8	35.8	39.8	55.6	54.9	60.5	59.7	53.1	48.5	42.2	42.8
1772.	33.8	35.6	39.6	43.3	49.7	60.3	61.0	61.0	56.1	53.7	44.7	40.9
1773.	38.5	36.5	42.0	45.3	48.6	56.5	59.5	62.2	54.9	49.5	40.5	39.6
1781.	.....	.....	.....	.....	.....	.....	.....	.....	57.9	49.8	43.0	42.4
1782.	40.5	35.8	39.8	41.8	49.2	58.8	60.2	58.0	56.6	46.5	36.0	37.6
1783.	38.5	40.6	38.8	49.0	49.4	59.3	66.7	62.0	55.7	50.3	43.8	36.4
1784.	30.8	33.3	37.3	43.1	57.9	57.1	60.5	57.5	58.4	45.2	42.0	32.4
1785.	37.7	31.8	35.0	47.3	53.6	60.3	63.2	58.8	57.9	48.2	41.5	36.6
1786.	37.5	37.6	35.3	45.8	53.4	60.5	60.0	60.2	52.4	46.0	38.0	

And these numbers may be considered as being very nearly the true values; they are reduced to the same zero as those in Table I. of my former paper, and form a part of that series of values.

Determination of the Mean Temperature of the Air at Epping for every month from the year 1821 to 1840.

Let us now proceed to compare the results of observations taken simultaneously towards the end of the Royal Society's series, made as nearly as possible under the

same circumstances as those at Lyndon at the beginning of that series, with the view of determining whether an agreement exists in the differences at those different epochs, and also for the purpose of assisting to determine whether London be really warmer than the country, as affirmed. The observations which most fully satisfy these conditions are those made by Mr. THOMAS SQUIRE of Epping. This gentleman, on my request to furnish me with the monthly means of his observations for comparison with those of this Society, most promptly and obligingly sent me the monthly mean from twenty-eight years' observations taken on every day at 8^h in the morning.

The thermometer with which the observations were made was placed in the shade, at the height of 5 feet above the ground, facing the N.E., and an open country.

These numbers I have reduced to mean values by the application of corrections, for that purpose (see my paper in Philosophical Transactions, Part I. 1848) then I further reduced them to the elevation at Somerset House and for difference of latitude, and in this way the next Table was formed.

TABLE XI.—Mean monthly temperature of the Air at Epping reduced to the elevation and latitude of Somerset House, for the year 1821 to 1848.

Year.	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	Year.
1821.	38·5	34·8	43·0	50·2	49·4	53·1	58·4	64·1	62·7	50·7	47·3	43·5	49·6
1822.	39·0	43·0	46·9	48·9	57·6	65·3	64·1	62·7	58·1	52·6	46·6	33·9	51·6
1823.	31·5	38·3	41·5	47·1	57·1	56·8	60·3	61·5	57·1	48·4	43·8	39·6	48·6
1824.	38·0	38·8	41·6	46·2	52·1	56·8	62·9	61·9	59·9	51·0	46·7	42·2	49·8
1825.	38·9	38·2	41·7	51·0	56·7	60·6	65·4	64·3	62·6	51·8	41·0	40·2	51·0
1826.	31·8	42·3	43·4	50·6	53·1	63·9	66·3	66·1	59·8	53·7	40·2	42·7	51·2
1827.	33·8	32·3	44·9	50·6	56·0	59·8	64·2	61·3	59·2	53·8	42·5	41·2	50·2
1828.	40·7	41·8	44·7	49·8	57·0	61·9	62·8	61·5	60·1	50·7	44·8	45·2	51·8
1829.	31·9	38·8	40·3	46·0	56·7	60·5	60·8	58·9	54·4	49·0	38·9	32·4	47·3
1830.	31·4	34·4	46·4	50·7	56·8	56·2	63·9	59·1	55·2	52·1	43·1	35·3	48·7
1831.	34·9	41·2	45·5	51·3	54·7	60·3	62·1	63·8	58·2	56·2	42·7	42·3	50·2
1832.	36·8	37·0	41·8	48·9	53·4	59·8	61·1	61·8	58·3	52·2	53·6	43·1	50·3
1833.	35·2	42·9	38·9	47·9	60·4	59·8	60·7	57·9	55·0	51·6	43·1	45·8	49·9
1834.	45·6	40·1	45·1	47·6	57·7	61·5	64·0	63·2	60·5	51·9	44·4	41·3	51·9
1835.	38·6	41·4	42·3	48·8	54·7	60·7	64·2	64·5	58·9	48·8	43·7	35·7	50·2
1836.	37·9	37·0	44·5	46·1	52·6	61·0	62·6	60·3	55·6	49·7	42·1	40·4	49·2
1837.	38·4	40·1	37·4	42·4	50·4	60·7	62·5	62·3	57·6	51·5	39·5	41·9	48·7
1838.	28·6	32·9	42·5	44·8	53·7	60·2	62·4	62·1	57·5	51·1	40·4	38·7	47·9
1839.	37·2	39·0	41·3	45·1	51·3	61·7	62·6	61·0	57·7	50·7	46·3	40·1	49·5
1840.	39·2	38·0	39·4	50·1	56·4	62·1	61·0	64·2	54·2	46·4	42·6	32·6	48·9
1841.	33·6	36·3	46·5	48·8	59·1	58·1	60·9	62·6	60·2	49·8	42·2	40·0	49·8
1842.	33·1	40·1	44·8	47·3	55·1	64·7	62·4	67·3	59·4	44·9	42·4	44·1	50·4
1843.	39·6	35·9	43·1	49·5	54·5	58·0	62·6	64·5	62·1	48·0	43·1	44·1	50·4
1844.	38·5	33·9	42·3	51·8	54·4	62·0	63·6	59·4	59·2	47·9	43·5	33·9	49·3
1845.	38·9	32·2	36·8	47·7	51·2	62·8	61·6	59·3	56·5	50·1	44·6	40·0	48·5
1846.	42·7	42·2	43·9	48·4	56·1	67·3	65·4	64·5	60·6	50·5	44·4	31·2	51·5
1847.	35·0	35·0	40·8	45·4	57·0	58·3	64·9	61·7	54·2	52·8	45·3	41·8	49·4
1848.	35·0	42·6	43·0	48·9	59·4	60·1	62·5	59·3	56·6	51·7	40·5	41·9	50·2

During twenty-two of these years observations were taken at Somerset House, and the following Table exhibits the simultaneous results with their differences.

TABLE XII.—Comparison of the mean monthly temperature of the Air at Somerset House and at Epping.

Year.	January.			February.			March.			April.			May.			June.		
	Mean temperature of the air at			Mean temperature of the air at			Mean temperature of the air at			Mean temperature of the air at			Mean temperature of the air at			Mean temperature of the air at		
	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.
1821.	38.1	38.5	+0.6	37.4	34.8	+2.6	43.9	43.0	+0.9	51.5	50.2	+1.3	50.1	49.4	+0.7	55.0	53.1	+1.9
1822.	41.4	39.0	+2.4	44.7	43.0	+1.7	48.4	46.9	+1.5	47.8	48.9	-1.1	56.9	57.6	-0.7	63.5	65.3	-1.8
1823.	33.4	31.5	+1.9	39.5	38.3	+1.2	40.9	41.5	-0.6	43.9	47.1	-3.2	55.7	57.1	-1.4	56.3	56.8	-0.5
1824.	39.0	37.6	+1.4	39.5	38.8	+0.7	40.6	41.6	-1.0	44.9	46.3	-1.4	50.6	52.1	-1.5	55.9	56.8	-0.9
1825.	40.0	38.9	+1.1	43.6	38.2	+5.4	39.6	40.7	-1.1	49.8	51.0	-1.2	54.7	56.7	-2.0	59.8	60.6	-0.8
1826.	33.6	31.8	+1.8	43.6	42.3	+1.3	44.3	43.4	+0.9	50.1	50.6	-0.5	51.1	53.1	-2.0	63.8	63.9	-0.1
1827.	35.0	33.8	+1.2	33.0	32.3	+0.7	44.2	44.9	-0.7	47.9	50.6	-2.7	53.8	56.0	-2.2	58.5	59.8	-1.3
1828.	41.4	40.7	+0.7	41.6	41.8	-0.2	44.6	44.7	-0.1	47.6	49.8	-2.2	55.4	57.0	-1.6	60.9	61.9	-1.0
1829.	33.3	31.9	+1.4	39.8	38.8	+1.0	40.1	40.3	-0.2	44.8	46.0	-1.2	55.6	56.7	-1.1	59.9	60.5	-0.6
1830.	32.3	31.4	+0.9	35.6	34.4	+1.2	46.9	46.4	+0.5	49.4	50.7	-1.3	55.8	56.8	-1.0	56.2	56.2	0.0
1831.	36.0	34.9	+1.1	42.6	41.2	+1.4	45.0	45.5	-0.5	49.2	51.3	-2.1	53.9	54.7	-0.8	60.3	60.3	0.0
1832.	38.9	36.8	+2.1	38.3	37.0	+1.3	41.6	41.8	-0.2	48.3	48.9	-0.6	52.6	53.4	-0.8	60.1	59.8	+0.3
1833.	36.1	35.2	+0.9	43.8	42.9	+0.9	38.7	38.9	-0.2	46.3	47.9	-1.6	60.5	60.4	+0.1	60.7	59.8	+0.9
1834.	46.0	45.6	+0.4	41.6	40.1	+1.5	41.1	45.1	-4.0	46.1	47.6	-1.5	58.0	57.7	+0.3	62.0	61.5	+0.5
1835.	39.6	38.6	+1.0	42.6	41.4	+1.2	42.1	42.3	-0.2	47.5	48.8	-1.3	54.0	54.7	-0.7	60.9	60.7	+0.2
1836.	38.8	37.9	+0.9	38.3	37.0	+1.3	44.8	44.5	+0.3	44.4	46.1	-1.7	53.9	52.6	+1.3	59.9	61.0	-1.1
1837.	38.8	38.4	+0.4	41.7	40.1	+1.6	36.9	37.4	-0.5	40.2	42.4	-2.2	48.9	50.4	-1.5	59.0	60.7	-1.7
1838.	30.5	28.6	+1.9	34.3	32.9	+1.4	42.6	42.5	+0.1	42.7	44.8	-2.1	51.8	53.7	-1.9	58.1	60.2	-2.1
1839.	38.8	37.2	+1.6	40.5	39.0	+1.5	38.1	41.3	-3.2	42.0	45.1	-3.1	51.0	51.3	-0.3	59.6	61.7	-2.1
1840.	40.6	39.2	+1.4	39.5	38.0	+1.5	38.7	39.4	-0.7	48.9	50.1	-1.2	54.6	56.4	-1.8	60.4	62.1	-1.7
1841.	36.1	33.6	+2.5	36.6	36.3	+0.3	47.9	46.5	+1.4	47.4	48.8	-1.4	57.9	59.1	-1.2	57.2	58.1	-0.9
1842.	31.8	33.1	-1.3	42.2	40.1	+2.1	45.4	44.8	+0.6	45.7	47.3	-1.6	54.3	55.1	-0.8	64.2	64.7	-0.5
1843.	41.3	39.6	+1.7	37.5	35.9	+1.6	43.6	43.1	+0.5	48.6	49.5	-0.9	52.8	54.5	-1.7	56.4	58.0	-1.6
	July.			August.			September.			October.			November.			December.		
	Mean temperature of the air at			Mean temperature of the air at			Mean temperature of the air at			Mean temperature of the air at			Mean temperature of the air at			Mean temperature of the air at		
	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.	Somerset House.	Epping.	Higher at Somerset House.
1821.	58.7	58.4	+0.3	63.0	64.1	-1.1	60.7	62.7	-2.0	51.6	50.7	+0.9	48.9	47.3	+1.6	45.7	43.5	+2.2
1822.	63.5	64.1	-0.6	62.6	63.7	-1.1	57.1	58.1	-1.0	53.3	53.6	+0.7	49.5	46.6	+2.9	37.8	33.9	+3.9
1823.	60.1	60.3	-0.2	61.6	61.5	+0.1	56.5	57.1	-0.6	48.9	48.4	+0.5	44.3	43.8	+0.5	41.3	39.6	+1.7
1824.	66.5	62.9	+0.6	61.3	61.9	-0.6	58.8	59.9	-1.1	51.1	51.0	+0.1	47.5	46.7	+0.8	43.2	42.2	+1.0
1825.	66.5	65.4	+0.8	63.1	64.3	-1.2	61.0	62.6	-1.6	53.1	51.8	+0.3	42.5	41.0	+1.5	42.0	40.2	+1.8
1826.	66.6	66.3	+0.3	64.7	66.1	-1.4	57.4	59.8	-2.4	53.7	53.7	0.0	41.2	40.2	+1.0	43.2	42.7	+0.5
1827.	64.5	64.2	+0.3	60.3	61.3	-1.0	58.0	59.2	-1.2	53.1	53.3	-0.2	42.8	42.5	+0.3	45.5	41.2	+4.3
1828.	62.9	62.8	+0.1	60.3	61.5	-1.2	58.6	60.1	-1.5	51.2	50.7	+0.5	45.6	44.8	+0.8	45.9	45.2	+0.7
1829.	61.1	60.8	+0.3	59.0	58.9	+0.1	54.3	54.4	-0.1	48.8	49.0	-0.2	40.6	38.9	+1.7	36.3	32.4	+3.9
1830.	64.0	63.9	+0.1	59.5	59.1	+0.4	54.6	55.2	-0.6	52.2	52.1	+0.1	45.7	43.1	+2.6	36.3	35.3	+1.0
1831.	63.3	62.1	+1.2	64.6	63.8	+0.8	57.5	58.2	-0.7	56.3	56.2	+0.1	45.6	43.7	+2.9	43.4	42.3	+1.1
1832.	62.3	61.1	+1.1	63.3	61.8	+0.5	57.7	58.3	-0.6	55.5	53.2	+2.3	45.0	43.6	+1.4	43.8	43.1	+0.7
1833.	62.1	60.7	+1.4	58.8	57.9	+0.9	57.9	55.0	-2.9	49.6	51.6	-2.0	44.8	43.1	+1.7	46.0	45.8	+0.2
1834.	65.1	64.0	+1.1	63.6	63.2	+0.4	59.4	60.5	-1.1	51.8	51.9	-0.1	45.4	44.4	+1.0	42.4	41.3	+1.1
1835.	63.4	64.2	-0.8	64.6	64.5	+0.1	58.2	58.9	-0.7	48.7	48.8	+0.5	44.3	43.7	+0.6	36.3	35.7	+0.6
1836.	63.9	62.6	+1.3	60.3	60.3	0.0	54.5	55.6	-1.1	48.7	49.7	-1.0	42.8	42.1	+0.7	41.0	40.4	+0.6
1837.	62.3	62.5	-0.2	61.4	62.3	-0.9	56.1	57.6	-1.5	51.9	51.5	+0.4	42.4	39.5	+2.9	42.6	41.9	+0.7
1838.	61.5	62.4	-0.9	60.9	62.1	-1.2	55.5	57.5	-2.0	51.3	51.1	+0.2	42.1	40.4	+1.7	40.0	38.7	+1.3
1839.	61.2	62.6	-1.4	60.2	61.0	-0.8	56.7	57.7	-1.0	50.2	50.7	-0.5	46.0	46.3	-0.3	41.0	40.1	+0.9
1840.	59.8	61.0	-1.2	63.4	64.2	-0.8	55.2	54.2	+1.0	48.1	46.4	+1.7	44.7	42.6	+2.1	34.7	32.6	+2.1
1841.	59.0	60.9	-1.9	61.3	62.6	-1.3	58.5	60.2	-1.7	50.7	49.8	+0.9	44.5	42.3	+2.2	42.0	40.0	+2.0
1842.	61.5	62.4	-0.9	67.6	67.3	+0.3	57.5	59.4	-1.9	47.2	44.9	+2.3	44.2	42.4	+1.8	45.3	44.1	+1.2

By taking the mean of the numbers in each column of differences, we find that the temperature of the air at the Apartments of the Royal Society in

January was higher than at Epping reduced to the same level by . . .	1·3
February was higher than at Epping reduced to the same level by . . .	1·2
March was lower than at Epping reduced to the same level by less than . . .	0·1
April was lower than at Epping reduced to the same level by . . .	1·5
May was lower than at Epping reduced to the same level by . . .	1·0
June was lower than at Epping reduced to the same level by . . .	0·6
July was higher than at Epping reduced to the same level by . . .	0·2
August was lower than at Epping reduced to the same level by . . .	0·3
September was lower than at Epping reduced to the same level by . . .	1·0
October was higher than at Epping reduced to the same level by . . .	0·2
November was higher than at Epping reduced to the same level by . . .	1·4
December was higher than at Epping reduced to the same level by . . .	1·5

And the mean temperature of the whole period was nearly of the same value at both places.

Having obtained these results, and finding that during the time the sun was situated north of the equator the temperature at the Apartments of the Royal Society was lower than at Epping, and that it was higher during the time the sun had south declination, I requested Mr. SQUIRE to furnish me with full particulars with respect to the position of his instrument to the sun and to surrounding objects: the following is the information he gave me:—

“The thermometer hangs near the north angle of a small projecting pier of a wall, nearly close to the brickwork, facing the N.E., and an open country. At the back of the wall is a grape-vine, and when in leaf, it so shades the wall that its temperature is not much affected by the sun’s rays; but, before the vine is in leaf, it may raise the temperature a trifle; yet from some casual observations scattered over my journal as tests, I do not find that the said thermometer is sensibly influenced by the heat of the sun at 8 A.M., the time of reading the instrument. On the 13th of May, 1847, I moved the thermometer a few feet from its former position on the wall, with the same aspect, but, at the back of this part of the wall, there is a sort of grotto or summer-house, which is covered by thatch and completely interrupts the sun’s rays from the wall; hence its present situation may perhaps be considered more eligible for a mean temperature than its former position, but I do not find any difference worth notice.”

The general fact, however, of a higher winter temperature, and of a lower summer temperature at the Apartments of the Royal Society, is satisfactorily proved by both sets of comparisons, and it is evident that the same cause has been in operation at both times, and to the same amount. There can be no doubt that this cause is the vicinity of the river Thames to the locality of the observations.

Determination of the Monthly Mean Temperature of the water of the Thames by night and by day, from the year 1846 to the year 1849.

The observations to determine the temperature of the Thames water are made by Lieut. SANDERS, R.N. The instruments consist of one maximum thermometer and of one minimum thermometer, suspended from the sides of the Dreadnought Hospital Ship, in a perforated trunk placed at about 2 feet below the surface of the water. The range of temperature during the day is usually about 2° , and the simple arithmetic mean of the readings of the maximum and minimum thermometers shows the mean temperature of the water.

TABLE XIII.—Mean monthly temperature of the water of the Thames.

Month.	1846.			1847.			1848.			1849.		
	Mean of all the readings in each month.		Mean temperature of the water.	Mean of all the readings in each month.		Mean temperature of the water.	Mean of all the readings in each month.		Mean temperature of the water.	Mean of all the readings in each month.		Mean temperature of the water.
	Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.	
January....	44.3	42.0	43.2	37.1	35.5	36.3	35.7	35.1	35.4	41.6	39.6	40.6
February...	45.3	42.5	43.9	38.9	37.2	38.1	41.8	40.3	41.1	44.2	42.6	43.4
March.....	48.2	46.3	47.3	42.1	41.4	41.8	.....	.....	.....	45.7	44.1	44.9
April	51.5	49.4	50.5	46.9	46.4	46.7	51.1	50.2	50.6	47.9	44.8	46.3
May	59.9	57.2	58.6	58.6	57.0	57.8	62.5	61.0	61.8	58.9	55.7	57.3
June	73.0	70.8	71.9	65.5	61.9	63.7	63.6	62.6	63.1	65.2	63.3	64.3
July	67.4	66.1	66.7	70.6	66.5	68.6	66.0	65.0	65.5	67.8	66.1	67.0
August ...	68.3	66.7	67.5	66.1	64.4	65.3	63.0	62.0	62.5	64.9	62.7	63.8
September.	64.7	63.5	64.1	57.0	56.5	56.8	59.5	58.8	59.1	61.4	58.7	60.0
October ...	54.2	52.8	53.5	53.3	53.0	53.2	53.7	50.8	52.2	52.8	49.5	51.2
November.	47.6	46.0	46.8	47.9	47.3	47.6	.....	.....	.....	47.1	44.1	45.6
December.	37.6	34.9	36.3	42.5	41.5	42.0	43.9	40.5	42.2	40.3	36.8	38.6

By comparing the means of these numbers for the four years, with the means of the readings of the maximum and minimum thermometers in air at the Royal Observatory, for the same months, we find that the mean lowest readings of the water were higher in the twelve months respectively by $3^{\circ}9$; $4^{\circ}6$; $7^{\circ}7$; $12^{\circ}3$; $11^{\circ}5$; $16^{\circ}7$; $12^{\circ}4$; $10^{\circ}4$; $10^{\circ}7$; $6^{\circ}8$; $6^{\circ}3$ and $4^{\circ}9$, than the mean of the lowest readings of the air; and it was lower than the mean maximum readings of the air by $3^{\circ}2$; $4^{\circ}6$; $5^{\circ}3$; $9^{\circ}2$; $6^{\circ}0$; $7^{\circ}5$; $8^{\circ}1$; $6^{\circ}7$; $7^{\circ}4$; $6^{\circ}0$; $4^{\circ}7$ and $3^{\circ}0$, in the respective months from January. These numbers are very large, and will fully account for the little higher temperature possessed by places in the vicinity of the river, and these differences of temperature are probably the fruitful source of the London fogs.

Mr. SANDERS, at my request, has taken daily observations of the temperature of the air at 32 feet above the water of the Thames at the hours of 6 A.M. and 6 P.M. during the years 1847 and 1848, and at the hours of 9 A.M. and 9 P.M. in the year 1849. The result of these observations, compared with simultaneous observations taken at the Royal Observatory, is as follows:—that the temperature of the air 32 feet above

the water, exceeds that at the observatory at 6 A.M. by $1^{\circ}6$; $1^{\circ}0$; $0^{\circ}8$; $0^{\circ}3$; $0^{\circ}6$; $0^{\circ}7$; $0^{\circ}9$; $0^{\circ}8$; $0^{\circ}2$; $0^{\circ}0$ and $0^{\circ}8$, in the twelve months respectively; and at 6 P.M. by $1^{\circ}2$; $0^{\circ}8$; $1^{\circ}0$; $0^{\circ}8$; $0^{\circ}7$; $0^{\circ}8$; $0^{\circ}6$; $0^{\circ}8$; $1^{\circ}3$; $1^{\circ}0$; $1^{\circ}7$ and $0^{\circ}9$, in the twelve months respectively; that at 9 A.M. it was in excess in January by $1^{\circ}3$; February by $1^{\circ}5$; March by $0^{\circ}6$; April by $0^{\circ}4$; May by $2^{\circ}2$; June by $0^{\circ}4$; and in October by $0^{\circ}5$; that it was of a lower temperature in July by $0^{\circ}7$; August by $0^{\circ}5$; and in September by $0^{\circ}1$; that at 9 P.M. it was always of a higher temperature: the excesses were $0^{\circ}1$; $0^{\circ}3$; $0^{\circ}7$; $0^{\circ}3$; $1^{\circ}9$; $2^{\circ}9$; $1^{\circ}5$; $3^{\circ}2$; $1^{\circ}2$ and $1^{\circ}3$ respectively.

From these numbers, it seems that during the night hours, at all seasons of the year, the temperature of the air at the Dreadnought Hospital Ship is higher than at the Observatory, and that it is below only during the midday hours.

At times of extreme temperature the effect of the water upon the temperature of the air is very great. On February 12, 1847, the temperature of the air at my house, which is situated about one mile and a half from the river, was $6^{\circ}0$; the lowest reading, 32 feet above the water of the Thames, was $16^{\circ}0$; the temperature of the water was 33° ; its heating effect upon the air in its immediate vicinity amounted to 10° ; at the Observatory the reading was $10^{\circ}5$; and the heat of the water of the Thames seems to have influenced the temperature of the air at the Observatory to the amount of 4° . Some time since, on comparing the temperatures of the air as recorded in the Philosophical Transactions in the year 1814, with corresponding temperatures as observed at Greenwich, I doubted the accuracy of the former in many instances, on account of their much higher values; these investigations have now led me to believe that the temperatures, as recorded in the Philosophical Transactions for that year, are correct.

TABLE XIV.—Comparison of the mean temperature of the Air at St. John's Wood, and at the Royal Observatory, Greenwich.

Month.	1841.			1842.			1843.		
	Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.		
	At Royal Observatory, Greenwich.	At St. John's Wood.	In excess at St. John's Wood.	At Royal Observatory, Greenwich.	At St. John's Wood.	In excess at St. John's Wood.	At Royal Observatory, Greenwich.	At St. John's Wood.	In excess at St. John's Wood.
January	$33^{\circ}6$	$34^{\circ}3$	$+0^{\circ}7$	$32^{\circ}9$	$32^{\circ}4$	$-0^{\circ}5$	$39^{\circ}9$	$39^{\circ}1$	$-0^{\circ}8$
February ...	$35^{\circ}3$	$36^{\circ}5$	$+1^{\circ}2$	$40^{\circ}8$	$40^{\circ}3$	$-0^{\circ}5$	$36^{\circ}0$	$36^{\circ}1$	$+0^{\circ}1$
March	$46^{\circ}2$	$46^{\circ}6$	$+0^{\circ}4$	$44^{\circ}9$	$44^{\circ}3$	$-0^{\circ}6$	$42^{\circ}9$	$42^{\circ}9$	$0^{\circ}0$
April	$47^{\circ}0$	$46^{\circ}6$	$-0^{\circ}4$	$45^{\circ}2$	$46^{\circ}3$	$+1^{\circ}1$	$47^{\circ}1$	$47^{\circ}6$	$+0^{\circ}5$
May	$56^{\circ}8$	$57^{\circ}0$	$+0^{\circ}2$	$53^{\circ}2$	$53^{\circ}2$	$0^{\circ}0$	$52^{\circ}2$	$51^{\circ}2$	$-1^{\circ}0$
June	$56^{\circ}4$	$55^{\circ}9$	$-0^{\circ}5$	$62^{\circ}9$	$62^{\circ}5$	$-0^{\circ}4$	$56^{\circ}3$	$55^{\circ}2$	$-1^{\circ}1$
July	$57^{\circ}8$	$56^{\circ}9$	$-0^{\circ}9$	$60^{\circ}2$	$59^{\circ}5$	$-0^{\circ}7$	$60^{\circ}9$	$60^{\circ}1$	$-0^{\circ}8$
August	$60^{\circ}5$	$59^{\circ}5$	$-1^{\circ}0$	$65^{\circ}4$	$65^{\circ}5$	$+0^{\circ}1$	$62^{\circ}1$	$61^{\circ}9$	$-0^{\circ}2$
September ...	$58^{\circ}5$	$57^{\circ}8$	$-0^{\circ}7$	$56^{\circ}4$	$56^{\circ}2$	$-0^{\circ}2$	$59^{\circ}5$	$60^{\circ}3$	$+0^{\circ}8$
October	$48^{\circ}8$	$49^{\circ}1$	$+0^{\circ}3$	$45^{\circ}4$	$45^{\circ}8$	$+0^{\circ}4$	$48^{\circ}0$	$47^{\circ}6$	$-0^{\circ}4$
November ...	$42^{\circ}7$	$42^{\circ}5$	$-0^{\circ}2$	$42^{\circ}8$	$43^{\circ}3$	$+0^{\circ}5$	$43^{\circ}8$	$43^{\circ}9$	$+0^{\circ}1$
December ...	$40^{\circ}5$	$40^{\circ}2$	$-0^{\circ}3$	$45^{\circ}0$	$44^{\circ}6$	$-0^{\circ}4$	$43^{\circ}9$	$44^{\circ}2$	$+0^{\circ}3$

TABLE XIV. (Continued.)

Month.	1844.			1845.			1846.		
	Mean temperature of the air.			Mean temperature of the air.			Mean temperature of the air.		
	At Royal Observatory Greenwich.	At St. John's Wood.	In excess at St. John's Wood.	At Royal Observatory, Greenwich.	At St. John's Wood.	In excess at St. John's Wood.	At Royal Observatory, Greenwich.	At St. John's Wood.	In excess at St. John's Wood.
January	39·1	36·9	−2·2	38·3	38·7	+0·4	43·7	43·1	−0·6
February ...	35·2	35·7	+0·5	32·7	32·9	+0·2	43·9	43·7	−0·2
March	41·5	41·6	+0·1	35·2	35·3	+0·1	43·3	44·0	+0·7
April	51·7	52·2	+0·5	46·3	47·5	+1·2	47·1	46·8	−0·3
May	52·9	52·5	−0·4	49·4	49·2	−0·2	54·6	55·6	+1·0
June	60·7	59·9	−0·8	60·7	60·6	−0·1	65·3	65·2	−0·1
July	61·4	61·0	−0·4	59·8	59·4	−0·4	64·5	63·6	−0·9
August	57·7	57·4	−0·3	57·3	57·6	+0·3	63·2	62·5	−0·7
September ...	56·9	57·4	+0·5	53·6	53·8	+0·2	60·1	60·1	0·0
October	49·5	49·2	−0·3	50·2	50·1	−0·1	50·5	49·9	−0·6
November ...	44·0	43·3	−0·7	45·8	45·3	−0·5	46·0	44·9	−1·1
December ...	33·0	33·8	+0·8	41·7	40·5	−1·2	32·9	32·7	−0·2

The observations at St. John's Wood consisted of one observation of the maximum thermometer and of one observation of the minimum thermometer, daily, as well as three observations at different times every day of other thermometers. They were made by GEORGE LEACH, Esq., to whom I am indebted for these results. The mean values for the month were obtained by the application of corrections from my tables. By examining the column of differences, no certain difference exists between the temperatures of the air at Greenwich and at St. John's Wood.

TABLE XV.—Mean monthly temperature of the Air at Fleet Street, London, as determined from observations taken by Mr. W. SIMMS, optician.

Year.	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
1838.	°	°	°	°	°	°	°	°	°	52·6	42·3	39·9
1839.	38·5	40·4	40·4	41·2	50·8	61·2	61·5	62·0	57·1	51·1	43·6	41·3
1840.	41·4	38·9	39·8	52·3	55·5	58·9	59·4	65·1	54·8	48·9	45·8	36·6
1841.	35·0	36·2	.....	.....	.....	.....	.....	.....	.....	.....	.....	47·6
1842.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	47·1
1843.	42·6	37·8	43·6	46·2	49·4	53·4	58·4	62·1	.....	47·3	45·9	47·1
1844.	43·6	35·8	43·5	49·3	50·0	58·2	60·8	56·8	57·5	50·4	44·8	36·7
1845.	41·8	35·2	37·0	46·0	46·9	55·6	58·6	56·2	54·3	51·2	47·8	44·3
1846.	46·1	45·4	47·8	45·9	53·9	62·3	.....	.....	.....	.....	.....	.....
1848.	35·9	44·3	43·0	47·9	57·9	55·9	63·4	57·4	58·0	52·1	44·1	45·0

These observations were taken with good instruments, and believed to be taken with every care: Mr. SIMMS very kindly lent me the original observations, from which I have deduced the above values. By comparison with the simultaneous observations taken at Greenwich, it seems that the temperature at Fleet Street upon the whole year is 0·7 higher than at Greenwich.

TABLE XVI.—Comparison of the temperature of the Air at Somerset House, and at the Royal Observatory, Greenwich, and deduction of the numbers in every month, necessary to be applied to reduce the mean values at one place to those at the other.

Year.	January.			February.			March.		
	Mean reading of the thermometer in air			Mean reading of the thermometer in air			Mean reading of the thermometer in air		
	At the Royal Observatory.	At Somerset House.	Higher at Somerset House.	At the Royal Observatory.	At Somerset House.	Higher at Somerset House.	At the Royal Observatory.	At Somerset House.	Higher at Somerset House.
1834.	44.1	46.0	1.9	40.5	41.6	1.1	43.8	45.1	1.3
1835.	37.7	39.6	1.9	41.0	42.6	1.6	41.2	42.1	0.9
1836.	38.5	38.8	0.3	37.1	38.3	1.2	43.7	44.8	1.1
1837.	38.3	38.8	0.5	41.2	41.7	0.5	36.0	36.9	0.9
1838.	28.3	30.5	2.2	32.1	34.3	2.2	41.6	42.6	1.0
1839.	36.6	38.8	2.2	39.6	40.5	0.9	38.4	40.1	1.7
1840.	39.6	40.6	1.0	37.0	39.5	2.5	37.2	38.7	1.5
1841.	33.6	36.1	2.5	35.3	36.6	1.3	46.2	47.9	1.7
1842.	32.9	34.8	1.9	40.8	42.2	1.4	44.9	45.4	0.5
1843.	39.9	41.3	1.4	36.0	37.5	1.5	42.9	43.6	0.7
	April.			May.			June.		
1834.	44.7	46.1	1.4	56.2	58.0	1.8	59.6	62.0	2.4
1835.	46.1	47.5	1.4	52.3	54.0	1.7	58.7	60.9	2.2
1836.	42.7	44.4	1.7	52.2	53.9	1.7	60.0	59.9	-0.1
1837.	39.6	40.2	0.6	48.6	48.9	0.3	60.9	59.0	-1.9
1838.	41.4	42.7	1.3	51.7	51.8	0.1	56.6	58.1	1.5
1839.	40.4	42.0	1.6	50.0	51.0	1.0	59.5	59.6	0.1
1840.	48.6	48.9	0.3	53.2	54.6	1.4	57.9	60.4	2.5
1841.	47.0	47.4	0.4	56.8	57.9	1.1	56.4	57.2	0.8
1842.	45.2	45.7	0.5	53.2	54.3	1.1	62.9	64.2	1.3
1843.	47.1	48.6	1.5	52.2	52.8	0.6	56.3	56.4	0.1
	July.			August.			September.		
1833.	59.7	62.1	2.4	56.9	58.8	1.9	53.0	54.6	1.6
1834.	64.0	65.1	1.1	61.5	63.6	2.1	57.0	59.4	2.4
1835.	63.9	65.4	1.5	63.0	64.6	1.6	57.6	58.2	0.6
1836.	62.8	63.9	1.1	59.8	60.2	0.4	53.7	54.5	0.8
1837.	.....	.....	.....	59.6	61.4	1.8	56.1	56.1	0.0
1838.	61.0	61.5	0.5	60.0	60.9	0.9	55.7	55.5	-0.2
1839.	60.8	61.2	0.4	58.6	60.2	1.6	55.5	56.7	1.2
1840.	59.3	59.0	-0.3	63.0	63.4	0.4	52.5	55.2	2.7
1841.	57.8	59.0	1.2	60.5	61.3	0.8	58.0	58.5	0.5
1842.	60.2	61.5	1.3	65.4	66.6	1.2	56.4	57.5	1.1
	October.			November.			December.		
1833.	50.5	49.6	-0.9	42.8	44.8	2.0	44.7	46.0	1.3
1834.	51.1	51.8	0.7	43.9	45.4	1.5	40.6	42.4	1.8
1835.	48.0	49.3	1.3	44.0	44.3	0.3	35.7	36.3	0.6
1836.	47.9	48.7	0.8	41.9	42.8	0.9	39.6	41.0	1.4
1837.	50.1	51.9	1.8	40.6	42.4	1.8	40.5	42.6	2.1
1838.	49.7	51.3	1.6	40.9	42.1	1.2	38.4	40.0	1.6
1839.	48.8	50.2	1.4	44.8	46.0	1.2	39.6	41.0	1.4
1840.	45.7	48.1	2.4	44.0	44.7	0.7	32.3	34.7	2.4
1841.	48.8	50.7	1.9	42.7	44.5	1.8	40.5	42.0	1.5
1842.	45.4	47.2	1.8	42.8	44.2	1.4	45.0	45.3	0.3

By taking the means of the numbers in each column of differences, we find that the temperature of the air at the Apartments of the Royal Society was

Higher than at the Royal Observatory, Greenwich, in January by . .	1.6
Higher than at the Royal Observatory, Greenwich, in February by . .	1.4
Higher than at the Royal Observatory, Greenwich, in March by . .	1.1
Higher than at the Royal Observatory, Greenwich, in April by . .	1.1
Higher than at the Royal Observatory, Greenwich, in May by . .	1.1
Higher than at the Royal Observatory, Greenwich, in June by . .	0.9
Higher than at the Royal Observatory, Greenwich, in July by . .	1.0
Higher than at the Royal Observatory, Greenwich, in August by . .	1.3
Higher than at the Royal Observatory, Greenwich, in September by .	1.1
Higher than at the Royal Observatory, Greenwich, in October by . .	1.3
Higher than at the Royal Observatory, Greenwich, in November by .	1.3
Higher than at the Royal Observatory, Greenwich, in December by .	1.4

And upon the whole year the excess of temperature at Somerset House was $1^{\circ}.2$; and to reduce readings taken at Somerset House to those at Greenwich, it is necessary to subtract the preceding numbers from them; and it is necessary to increase the readings of the Royal Observatory by the above numbers to make them comparable with those taken at the Royal Society.

One part of these differences is owing to the difference of elevation, and which will amount to about $0^{\circ}.3$; the greater part of the remaining difference is most probably owing to the vicinity of the water of the Thames, whose temperature during the night hours, at all seasons of the year, is several degrees higher than that of the air (see remarks following Table XIII.).

The general result of the preceding investigations, with respect to the temperatures of London and the country is, that those parts of London situated near the river Thames, are somewhat warmer upon the whole year than the country, but that those parts of London which are situated at some distance from the river, do not enjoy higher temperatures than those due to their latitudes.

I proceed now to reduce the results at Somerset House to those of the Royal Observatory, Greenwich, by applying the numbers following the preceding Table to the numbers in Table I. of my former paper, and to those in Table X. till the year 1840. After this date the numbers are extracted from the several volumes of the Greenwich Meteorological Observations.

TABLE XVII.—Showing the mean temperature of each month at the Royal Observatory, Greenwich, as found from the numbers in Table I. of my former paper till the year 1840, and from the observations at Greenwich from the year 1841.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1771.	29.9	33.4	34.7	38.7	54.5	54.0	59.5	58.4	52.0	47.2	40.9	41.4
1772.	32.2	34.2	38.5	42.2	48.6	59.4	60.0	59.7	55.0	52.4	43.4	39.5
1773.	36.9	34.9	40.9	44.2	47.5	55.6	58.5	60.9	53.8	48.2	39.2	38.2
1774.	31.5	38.0	42.8	46.8	51.1	60.1	61.8	62.4	54.7	48.8	39.2	37.1
1775.	40.4	41.9	41.7	49.7	54.1	62.6	63.0	60.8	58.4	48.2	40.2	39.3
1776.	27.0	40.0	43.7	47.2	50.6	58.7	62.8	60.7	54.5	51.5	42.7	40.1
1777.	33.9	35.8	44.6	44.0	52.3	56.3	60.5	62.4	58.1	51.3	43.7	35.8
1778.	34.8	35.6	40.1	46.9	54.8	61.3	67.0	63.5	53.4	46.0	44.7	42.8
1779.	34.8	45.3	47.0	50.7	54.7	58.0	64.9	63.9	60.7	51.9	41.9	40.2
1780.	28.6	35.3	49.2	43.6	56.1	59.1	63.2	65.7	59.3	50.0	39.5	36.6
1781.	36.2	40.3	42.6	46.1	53.1	62.5	65.3	63.0	56.8	48.5	41.7	41.0
1782.	38.9	34.4	38.7	40.7	48.1	57.9	59.2	56.7	55.5	45.2	34.7	36.2
1783.	36.9	39.2	37.7	47.9	48.3	58.4	65.7	60.7	54.6	49.0	42.5	35.0
1784.	29.2	31.9	36.2	42.0	56.8	56.2	59.5	56.2	57.3	43.9	40.7	31.0
1785.	36.1	30.4	33.9	46.2	52.5	59.4	62.2	57.5	56.8	46.9	40.2	35.2
1786.	35.9	36.2	34.2	44.7	52.3	59.6	59.0	58.9	51.3	44.7	36.7	35.9
1787.	36.7	39.5	42.8	44.4	51.3	57.8	61.4	61.1	54.4	48.6	39.6	39.6
1788.	37.4	38.7	38.6	49.5	56.3	58.6	60.6	59.9	55.9	49.1	40.6	29.0
1789.	33.4	39.9	34.4	44.1	53.2	54.8	58.8	60.2	54.6	46.8	38.7	41.6
1790.	38.6	41.2	43.2	40.9	52.6	56.8	59.1	59.9	53.9	49.5	42.0	39.0
1791.	39.8	38.8	42.1	48.8	49.4	57.6	59.5	61.4	56.8	46.6	41.3	34.8
1792.	34.9	37.4	42.1	48.9	49.6	54.4	58.6	62.2	55.4	48.7	43.2	40.0
1793.	35.3	39.7	39.3	42.4	50.7	55.4	64.9	59.0	52.8	51.9	42.9	41.0
1794.	33.3	44.7	44.3	49.6	50.6	57.6	65.3	59.4	53.7	48.3	43.3	36.8
1795.	23.9	34.1	38.6	45.1	51.9	53.7	58.9	60.8	60.8	53.4	40.7	44.8
1796.	45.3	39.6	39.0	48.3	50.1	56.1	58.6	59.9	59.1	46.5	40.3	30.4
1797.	35.4	35.6	37.9	44.7	51.3	54.8	63.3	59.0	54.6	47.0	41.4	41.2
1798.	37.8	37.9	40.7	49.2	53.6	61.2	61.2	61.5	56.5	49.8	40.0	33.7
1799.	33.3	36.4	37.2	41.5	49.5	55.6	59.8	57.5	54.3	47.3	42.9	32.8
1800.	36.9	34.1	37.5	48.4	54.0	55.1	63.2	63.7	57.9	47.9	42.2	38.2
1801.	39.5	38.5	44.1	45.4	53.6	58.4	60.5	62.5	58.7	50.9	40.2	36.1
1802.	32.9	38.9	41.2	48.5	50.2	57.6	56.5	64.8	57.0	49.5	40.5	37.8
1803.	33.4	36.3	42.3	47.8	50.1	56.2	63.7	61.7	52.4	48.9	41.9	43.3
1804.	43.2	36.9	41.1	43.7	56.6	61.3	60.2	59.9	59.4	51.4	44.1	35.6
1805.	34.5	38.7	42.0	45.3	49.6	54.5	59.1	61.7	59.3	47.4	39.9	39.5
1806.	40.6	41.5	40.7	43.0	55.0	59.8	61.2	61.4	57.0	51.2	47.4	46.8
1807.	36.7	40.0	37.0	45.4	55.0	57.7	63.5	63.7	53.1	53.0	38.7	36.6
1808.	37.0	36.3	37.1	42.5	57.1	58.0	65.7	62.5	55.3	46.1	43.9	36.0
1809.	35.4	44.1	42.6	41.1	55.7	57.5	59.6	58.9	56.1	49.6	39.5	41.0
1810.	34.4	38.6	42.2	46.4	49.7	58.5	60.9	60.5	59.4	51.8	42.8	38.6
1811.	32.8	40.1	43.4	48.7	56.2	57.6	61.0	58.5	57.9	55.5	45.2	38.6
1812.	35.9	41.6	38.4	41.5	51.2	54.0	57.4	57.0	55.9	48.8	40.6	35.1
1813.	34.4	41.6	43.1	43.8	52.3	55.3	58.9	58.3	54.5	47.3	40.2	36.6
1814.	26.9	34.0	35.1	48.1	48.6	53.4	61.1	58.6	54.9	47.3	40.7	41.1
1815.	31.9	41.2	45.0	46.6	54.7	58.0	59.9	60.4	62.3	51.4	38.9	37.0
1816.	36.7	36.6	39.2	43.4	48.8	53.1	54.5	57.9	58.9	50.8	39.3	37.8
1817.	39.2	42.6	41.6	43.9	47.9	59.1	57.7	55.4	55.5	45.0	46.9	37.1
1818.	39.3	35.8	40.9	45.6	52.5	62.9	66.2	63.6	60.7	53.7	49.2	38.8
1819.	40.1	40.0	44.0	48.2	54.2	56.4	61.7	63.8	58.1	47.5	40.8	37.0
1820.	31.7	36.9	41.3	49.3	52.0	56.1	59.5	58.5	54.4	47.0	41.4	39.9
1821.	37.5	36.0	42.8	50.4	49.4	54.1	57.7	61.7	59.6	50.3	47.6	44.3
1822.	39.8	43.3	47.3	46.7	55.8	62.6	62.5	61.3	56.0	52.0	48.2	36.4
1823.	31.8	38.1	39.8	42.8	54.6	55.4	59.1	59.8	55.4	47.6	43.0	39.9
1824.	37.4	36.2	39.5	43.8	49.5	55.0	62.5	60.0	57.7	49.8	46.2	41.8
1825.	38.4	38.1	38.5	48.7	53.6	58.9	65.2	61.8	59.9	50.8	41.2	40.6
1826.	32.0	42.2	43.2	49.0	50.0	62.9	65.6	63.4	56.3	52.4	39.9	41.8
1827.	33.4	31.6	43.1	46.8	52.7	57.6	63.5	59.0	56.9	51.8	41.5	44.1
1828.	39.8	40.2	43.5	46.5	54.3	60.0	61.9	59.0	57.5	49.9	44.3	44.5
1829.	31.7	38.4	39.0	43.7	54.5	59.0	60.1	57.7	53.2	47.5	39.3	34.9
1830.	30.7	34.2	45.8	48.3	54.7	55.3	63.0	58.2	53.5	50.9	44.4	34.9
1831.	34.4	41.2	43.9	48.1	52.8	59.4	64.3	63.3	56.4	55.0	44.3	42.0
1832.	37.3	36.9	40.5	47.2	51.5	59.2	61.2	61.0	56.6	51.2	43.7	42.4
1833.	34.5	42.4	37.6	45.2	59.4	59.8	61.1	57.5	53.5	48.3	43.5	44.6
1834.	44.4	40.2	44.0	45.0	56.9	61.1	64.1	62.3	58.3	50.5	44.1	41.0
1835.	38.0	41.2	41.0	46.4	52.9	60.0	64.4	63.3	57.1	48.0	43.0	34.9
1836.	37.2	36.9	43.7	43.3	52.8	59.0	62.9	58.9	53.4	47.4	41.5	39.6
1837.	37.2	40.3	35.8	39.1	47.8	58.1	61.3	60.1	55.0	50.6	41.1	41.2
1838.	28.9	32.9	41.5	41.6	50.7	57.2	60.5	59.6	54.4	50.0	40.8	38.6
1839.	37.2	39.1	39.0	40.9	49.9	58.7	60.2	58.9	55.6	48.9	44.7	39.6
1840.	39.0	38.1	37.6	47.8	53.5	59.5	58.0	62.1	54.1	46.8	43.4	33.3
1841.	33.6	35.3	46.2	47.0	56.8	56.4	57.8	60.5	58.1	48.8	42.7	40.5
1842.	32.9	40.8	44.9	45.2	53.2	62.9	60.2	65.4	56.4	45.4	42.8	45.0
1843.	39.9	36.0	42.9	47.1	52.2	56.3	60.9	62.1	59.5	48.0	43.8	43.9
1844.	39.1	35.2	41.5	51.7	52.9	60.7	61.4	57.7	56.9	49.5	44.0	33.0
1845.	38.3	32.7	35.2	46.3	49.4	60.7	59.8	57.3	53.6	50.2	45.8	41.7
1846.	43.7	43.9	43.3	47.1	54.6	65.3	64.5	63.2	60.1	50.5	46.0	32.9
1847.	35.1	35.4	41.0	45.3	56.4	58.0	65.4	62.1	54.3	52.9	46.9	42.8
1848.	34.6	43.4	43.8	47.6	59.7	58.5	61.5	58.5	55.8	51.6	43.8	44.0
1849.	40.1	43.2	42.5	43.2	54.0	57.9	62.1	62.9	58.8	51.1	44.1	39.1

By taking the means of the numbers in each column, we find that

The mean temperature of January from all the observations is . . . 35°7
 The mean temperature of February from all the observations is . . . 38°2
 The mean temperature of March from all the observations is . . . 40°9
 The mean temperature of April from all the observations is . . . 45°7
 The mean temperature of May from all the observations is . . . 52°6
 The mean temperature of June from all the observations is . . . 58°0
 The mean temperature of July from all the observations is . . . 61°3
 The mean temperature of August from all the observations is . . . 60°5
 The mean temperature of September from all the observations is . . . 56°3
 The mean temperature of October from all the observations is . . . 49°3
 The mean temperature of November from all the observations is . . . 42°4
 The mean temperature of December from all the observations is . . . 38°8
 And the mean of all the monthly results is 48°3.

TABLE XVIII.—Showing the Highest and Lowest monthly mean temperature in every year from 1771 to 1849, with the amount of difference of temperature.

Year.	Monthly mean temperature.		Difference between the hottest and coldest months.	Month of temperature.		Year.	Monthly mean temperature.		Difference between the hottest and coldest months.	Month of temperature.	
	Highest.	Lowest.		Highest.	Lowest.		Highest.	Lowest.		Highest.	Lowest.
1771.	59·5	29·9	29·6	July.	January.	1811.	61·0	32·8	28·2	July.	January.
1772.	60·0	32·2	27·8	July.	January.	1812.	57·4	35·1	22·3	July.	December.
1773.	60·9	34·9	26·0	August.	February.	1813.	58·9	34·4	24·5	July.	January.
1774.	62·4	31·5	30·3	January.	August.	1814.	61·1	26·9	34·2	July.	January.
1775.	63·0	39·3	23·7	July.	December.	1815.	62·3	31·9	30·4	September.	January.
1776.	62·8	27·0	35·8	July.	January.	1816.	58·9	36·6	22·3	September.	February.
1777.	62·4	33·9	28·5	August.	January.	1817.	59·1	37·1	22·0	June.	December.
1778.	67·0	34·8	32·2	July.	January.	1818.	66·2	35·8	30·4	July.	February.
1779.	64·9	34·8	30·1	July.	January.	1819.	63·8	37·0	26·8	August.	December.
1780.	65·7	28·6	37·1	August.	January.	1820.	59·5	31·7	27·8	July.	January.
1781.	65·3	36·2	29·1	July.	January.	1821.	61·7	36·0	25·7	August.	February.
1782.	59·2	34·4	24·8	July.	February.	1822.	62·6	36·4	26·2	June.	December.
1783.	65·7	35·0	30·7	July.	December.	1823.	59·8	31·8	28·0	August.	January.
1784.	59·5	29·2	30·3	July.	January.	1824.	62·5	36·2	26·3	July.	February.
1785.	62·2	30·4	31·8	July.	February.	1825.	65·2	38·1	27·1	July.	February.
1786.	59·6	35·9	23·7	June.	Jan. and Dec.	1826.	65·6	32·0	33·6	July.	January.
1787.	61·4	36·7	24·7	July.	January.	1827.	63·5	31·6	31·9	July.	February.
1788.	60·6	29·0	31·6	July.	December.	1828.	61·9	39·8	22·1	July.	January.
1789.	60·2	33·4	26·8	August.	January.	1829.	60·1	31·7	28·4	July.	January.
1790.	59·9	38·6	21·3	August.	January.	1830.	63·0	30·7	32·3	July.	January.
1791.	61·4	34·8	26·6	August.	December.	1831.	64·3	34·4	29·9	July.	January.
1792.	62·2	34·9	27·3	August.	January.	1832.	61·2	36·9	24·3	July.	February.
1793.	64·9	35·3	29·6	July.	January.	1833.	61·1	34·5	26·6	July.	January.
1794.	65·3	33·3	32·0	July.	January.	1834.	64·1	40·2	23·9	July.	February.
1795.	60·8	23·9	36·9	Aug. and Sept.	January.	1835.	64·4	34·9	29·5	July.	December.
1796.	59·9	30·4	29·5	August.	December.	1836.	62·9	36·9	26·0	July.	February.
1797.	63·3	35·4	27·9	July.	January.	1837.	61·3	35·8	25·5	July.	March.
1798.	61·5	33·7	27·8	August.	December.	1838.	60·5	28·9	31·6	July.	January.
1799.	59·8	32·8	27·0	July.	December.	1839.	60·2	37·2	23·0	July.	January.
1800.	63·7	34·1	29·6	August.	February.	1840.	62·1	33·3	28·8	August.	December.
1801.	62·5	36·1	26·4	August.	December.	1841.	60·5	33·6	26·9	August.	January.
1802.	64·8	32·9	31·9	August.	January.	1842.	65·4	32·9	32·5	August.	January.
1803.	63·7	33·4	30·3	July.	January.	1843.	62·1	36·0	26·1	August.	February.
1804.	60·2	35·6	24·6	July.	December.	1844.	61·4	33·0	28·4	July.	December.
1805.	61·7	34·5	27·2	August.	January.	1845.	60·7	32·7	28·0	June.	February.
1806.	61·4	40·6	20·8	August.	January.	1846.	65·3	32·9	32·4	June.	December.
1807.	63·7	36·6	27·1	August.	December.	1847.	65·4	35·1	30·3	July.	January.
1808.	65·7	36·0	29·7	July.	December.	1848.	61·5	34·6	26·9	July.	January.
1809.	59·6	35·4	24·2	July.	January.	1849.	62·9	39·1	23·8	August.	December.
1810.	60·9	34·4	26·5	July.	January.						

The mean of all the differences between the hottest and coldest months in every year is $28^{\circ}5$.

In the year 1790 the difference was $21^{\circ}3$ only, and in the year 1780 it was as large as $37^{\circ}1$, these numbers being respectively the smallest and largest within the period of seventy-nine years.

The coldest month in the year has occurred in January forty-three times, in February fifteen, in December twenty-one, and in March once; this unusual circumstance took place in the year 1837.

The hottest month in the year has taken place five times in June, forty-seven times in July, twenty-five times in August, and three times in September.

The following are the values of the extreme mean temperatures in every month:—

In January	1795 the mean temperature was $23^{\circ}9$, and in January	1796 it was $45^{\circ}3$.
In February	1785 the mean temperature was $30^{\circ}4$, and in February	1794 it was $44^{\circ}7$.
In March	1785 the mean temperature was $33^{\circ}9$, and in March	1780 it was $49^{\circ}2$.
In April	1771 the mean temperature was $38^{\circ}7$, and in April	1844 it was $51^{\circ}7$.
In May	1773 the mean temperature was $47^{\circ}5$, and in May	1848 it was $59^{\circ}7$.
In June	1816 the mean temperature was $53^{\circ}1$, and in June	1846 it was $65^{\circ}3$.
In July	1816 the mean temperature was $54^{\circ}5$, and in July	1778 it was $67^{\circ}0$.
In August	1817 the mean temperature was $55^{\circ}4$, and in August	1780 it was $65^{\circ}7$.
In September	1786 the mean temperature was $51^{\circ}3$, and in September	1815 it was $62^{\circ}3$.
In October	1784 the mean temperature was $43^{\circ}9$, and in October 1811 and 1831 it was $55^{\circ}0$.	
In November	1782 the mean temperature was $34^{\circ}7$, and in November	1822 it was $48^{\circ}2$.
In December	1788 the mean temperature was $29^{\circ}0$, and in December	1806 it was $46^{\circ}8$.

It is clear from these numbers that observations for a few years only can never be of great importance, when we consider that the difference of the monthly means of the winter months may be as large as 20° , and of the summer months of 11° or 12° .

By taking the means of the numbers in the Table in different groups of years the next Table is formed.

TABLE XIX.—Showing the mean temperature of the Air at the Royal Observatory, Greenwich, in every month in successive groups of years.

Period.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
From 1771 to 1779.	$33^{\circ}5$	$37^{\circ}7$	$41^{\circ}6$	$45^{\circ}6$	$52^{\circ}0$	$58^{\circ}4$	$62^{\circ}0$	$61^{\circ}2$	$55^{\circ}6$	$49^{\circ}5$	$41^{\circ}8$	$39^{\circ}4$
From 1780 to 1789.	$34^{\circ}9$	$36^{\circ}6$	$38^{\circ}8$	$44^{\circ}9$	$52^{\circ}8$	$58^{\circ}4$	$61^{\circ}5$	$60^{\circ}0$	$55^{\circ}7$	$47^{\circ}3$	$40^{\circ}5$	$36^{\circ}1$
From 1790 to 1799.	$35^{\circ}8$	$38^{\circ}5$	$40^{\circ}4$	$45^{\circ}9$	$50^{\circ}9$	$56^{\circ}3$	$60^{\circ}9$	$60^{\circ}1$	$55^{\circ}8$	$48^{\circ}9$	$41^{\circ}8$	$37^{\circ}5$
From 1800 to 1809.	$37^{\circ}0$	$38^{\circ}5$	$40^{\circ}6$	$45^{\circ}1$	$53^{\circ}7$	$57^{\circ}6$	$61^{\circ}3$	$62^{\circ}1$	$56^{\circ}6$	$49^{\circ}6$	$41^{\circ}8$	$39^{\circ}1$
From 1810 to 1819.	$35^{\circ}2$	$39^{\circ}2$	$41^{\circ}3$	$45^{\circ}6$	$51^{\circ}6$	$56^{\circ}8$	$59^{\circ}9$	$59^{\circ}4$	$57^{\circ}8$	$49^{\circ}9$	$42^{\circ}4$	$37^{\circ}8$
From 1820 to 1829.	$35^{\circ}4$	$38^{\circ}1$	$41^{\circ}8$	$46^{\circ}8$	$52^{\circ}6$	$58^{\circ}2$	$61^{\circ}8$	$60^{\circ}2$	$56^{\circ}7$	$49^{\circ}9$	$43^{\circ}3$	$40^{\circ}8$
From 1830 to 1839.	$36^{\circ}0$	$38^{\circ}5$	$41^{\circ}3$	$44^{\circ}5$	$52^{\circ}9$	$58^{\circ}8$	$62^{\circ}3$	$60^{\circ}3$	$55^{\circ}4$	$50^{\circ}1$	$43^{\circ}1$	$39^{\circ}9$
From 1840 to 1849.	$37^{\circ}6$	$38^{\circ}4$	$41^{\circ}9$	$46^{\circ}9$	$54^{\circ}3$	$59^{\circ}6$	$61^{\circ}2$	$61^{\circ}2$	$56^{\circ}8$	$49^{\circ}5$	$44^{\circ}0$	$39^{\circ}7$

The next Table is formed by taking the difference between the mean temperature of each month, as found from all the years, and the mean temperature of the same month in every year.

TABLE XX.—Showing the excess of the monthly mean temperature at Greenwich, in every year, above the mean temperature of the month from all the years.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1771.	- 5.8	- 4.8	- 6.2	- 7.0	+ 1.9	- 4.0	- 1.8	- 2.1	- 4.3	- 2.1	- 1.5	+ 2.6
1772.	- 3.5	- 4.0	- 2.4	- 3.5	- 4.0	+ 1.4	- 1.3	- 0.8	- 1.3	+ 3.1	+ 1.0	+ 0.7
1773.	+ 1.2	- 3.3	0.0	- 1.5	- 5.1	- 2.4	- 2.8	+ 0.4	- 2.5	- 1.1	- 3.2	- 0.6
1774.	- 4.2	- 0.2	+ 1.9	+ 1.1	- 1.5	+ 2.1	+ 0.5	+ 1.9	- 1.6	- 0.5	- 3.2	- 1.7
1775.	+ 4.7	+ 3.7	+ 0.8	+ 4.0	+ 1.5	+ 4.6	+ 1.7	+ 0.3	+ 2.1	- 1.1	- 2.2	+ 0.5
1776.	- 8.7	+ 1.8	+ 2.8	+ 1.5	- 2.0	+ 0.7	+ 1.5	+ 0.2	- 1.8	+ 2.2	+ 0.3	+ 1.3
1777.	- 1.8	- 2.4	+ 3.7	- 1.7	- 0.3	- 1.7	- 0.8	+ 1.9	+ 1.8	+ 2.0	+ 1.3	- 3.0
1778.	- 0.9	- 2.6	- 0.8	+ 1.2	+ 2.2	+ 3.3	+ 5.7	+ 3.0	- 2.9	- 3.3	+ 2.3	+ 4.0
1779.	- 0.9	+ 7.1	+ 6.1	+ 5.0	+ 2.1	0.0	+ 3.6	+ 3.4	+ 4.4	+ 2.6	- 0.5	+ 1.4
1780.	- 7.1	- 2.9	+ 8.3	- 2.1	+ 3.5	+ 1.1	+ 1.9	+ 5.2	+ 3.0	+ 0.7	- 2.9	- 2.2
1781.	+ 0.5	+ 2.1	+ 1.7	+ 0.4	+ 0.5	+ 4.5	+ 4.0	+ 2.5	+ 0.5	- 0.8	- 0.7	+ 2.2
1782.	+ 3.2	- 3.8	- 2.2	- 5.0	- 4.5	- 0.1	- 2.1	- 3.8	- 0.8	- 4.1	- 7.7	- 2.6
1783.	+ 1.2	+ 1.0	- 3.2	+ 2.2	- 4.3	+ 0.4	+ 4.4	+ 0.2	- 1.7	- 0.3	+ 0.1	- 3.8
1784.	- 6.5	- 6.3	- 4.7	- 3.7	+ 4.2	- 1.8	- 1.8	- 4.3	+ 1.0	- 5.4	- 1.7	- 7.8
1785.	+ 0.4	- 7.8	- 7.0	+ 0.5	- 0.1	+ 1.4	+ 0.9	- 3.0	+ 0.5	- 2.4	- 2.2	- 3.6
1786.	+ 0.2	- 2.0	- 6.7	- 1.0	- 0.3	+ 1.6	- 2.3	- 1.6	- 5.0	- 4.6	- 5.7	- 2.9
1787.	+ 1.0	+ 1.3	+ 1.9	- 1.3	- 1.3	- 0.2	+ 0.1	+ 0.6	- 1.9	- 0.7	- 2.8	+ 0.8
1788.	+ 1.7	+ 0.5	- 2.3	+ 3.8	+ 3.7	+ 0.6	- 0.7	- 0.6	- 0.4	- 0.2	- 1.8	- 9.8
1789.	- 2.3	+ 1.7	- 6.5	- 1.6	+ 0.6	- 3.2	- 2.5	- 0.3	- 1.7	- 2.5	- 3.7	+ 2.8
1790.	+ 2.9	+ 3.0	+ 2.3	- 4.8	0.0	- 1.2	- 2.2	- 0.6	- 2.4	+ 0.2	- 0.4	+ 0.2
1791.	+ 4.1	+ 0.6	+ 1.2	+ 3.1	- 3.2	- 0.4	- 1.8	+ 0.9	+ 0.5	- 2.7	- 1.1	- 4.0
1792.	- 0.8	- 0.8	+ 1.2	+ 3.2	- 3.0	- 3.6	- 2.7	+ 1.7	- 0.9	- 0.6	+ 0.8	+ 1.2
1793.	- 0.4	+ 1.5	- 1.6	- 3.3	- 1.9	- 2.6	+ 3.6	- 1.5	- 3.5	- 2.6	+ 0.5	+ 2.2
1794.	- 2.4	+ 6.5	+ 3.4	+ 3.9	- 2.0	- 0.4	+ 4.0	- 1.1	- 2.6	- 1.0	+ 0.9	- 2.0
1795.	- 11.8	- 4.1	- 2.3	- 0.6	- 0.7	- 4.3	- 2.4	+ 0.3	+ 4.5	+ 4.1	- 1.7	+ 6.0
1796.	+ 9.6	+ 1.4	- 1.9	+ 2.6	- 2.5	- 1.9	- 2.7	- 0.6	+ 2.8	- 2.8	- 2.1	- 8.4
1797.	- 0.3	- 2.6	- 3.0	- 1.0	- 1.3	- 3.2	+ 2.0	- 1.5	- 1.7	- 2.3	- 1.0	+ 2.4
1798.	+ 2.1	- 0.3	- 0.2	+ 3.5	+ 1.0	+ 3.2	- 0.1	+ 1.0	+ 0.2	+ 0.5	- 2.4	- 5.1
1799.	- 2.4	- 1.8	- 3.7	- 4.2	- 3.1	- 2.4	- 1.5	- 0.5	- 2.0	- 2.0	+ 0.5	- 6.0
1800.	+ 1.2	- 4.1	- 3.4	+ 2.7	+ 1.4	- 2.9	+ 1.9	+ 3.2	+ 1.6	- 1.4	- 0.2	- 0.6
1801.	+ 3.8	+ 0.3	+ 3.2	- 0.3	+ 1.0	+ 0.4	- 0.8	+ 2.0	+ 2.4	+ 1.6	- 2.2	- 2.7
1802.	- 2.8	+ 0.7	+ 0.3	+ 2.8	- 2.4	- 0.4	- 4.8	+ 4.3	+ 0.7	+ 0.2	- 1.9	- 1.0
1803.	- 2.3	- 1.9	+ 1.4	+ 2.1	- 2.5	- 1.8	+ 2.4	+ 1.2	- 3.9	- 0.4	- 0.5	+ 4.5
1804.	+ 7.5	- 1.3	+ 0.2	- 2.0	+ 4.0	+ 3.3	- 1.1	- 0.6	+ 3.1	+ 2.1	+ 1.7	- 3.2
1805.	- 1.2	+ 0.5	+ 1.1	- 0.4	- 3.0	- 3.5	- 2.2	+ 1.2	+ 3.0	- 1.9	- 2.5	+ 0.7
1806.	+ 4.9	+ 3.3	- 0.2	- 2.7	+ 2.4	+ 1.8	- 0.1	+ 0.9	+ 0.7	+ 1.9	+ 5.0	+ 8.0
1807.	+ 1.0	+ 1.8	- 3.9	- 0.3	+ 2.4	- 0.3	+ 2.2	+ 3.2	- 3.2	+ 3.7	- 3.7	- 2.2
1808.	+ 1.3	- 1.9	- 3.8	- 3.2	+ 4.5	0.0	+ 4.4	+ 2.0	- 1.0	- 3.2	+ 1.5	- 2.8
1809.	- 0.3	+ 5.9	+ 1.7	- 4.6	+ 3.1	- 0.5	- 1.7	- 1.6	- 0.2	+ 0.3	- 2.9	+ 2.2
1810.	- 1.3	+ 0.4	+ 1.3	+ 0.7	- 2.9	+ 0.5	- 0.4	0.0	+ 3.1	+ 2.5	+ 0.4	- 0.2
1811.	- 2.9	+ 1.9	+ 2.5	+ 3.0	+ 3.3	- 0.4	- 0.3	- 2.0	+ 1.6	+ 6.2	+ 2.8	- 0.2
1812.	+ 0.2	+ 3.4	- 2.5	- 4.2	- 1.4	- 4.0	- 3.9	- 3.5	- 0.4	- 0.5	- 1.8	- 3.7
1813.	- 1.3	+ 3.4	+ 2.2	- 1.9	- 0.3	- 2.7	- 2.4	- 2.2	- 1.8	- 2.0	- 2.2	- 2.2
1814.	- 8.8	- 4.2	- 5.8	+ 2.4	- 4.0	- 4.6	- 0.2	- 1.9	- 1.4	- 2.0	- 1.7	+ 2.3
1815.	- 3.8	+ 3.0	+ 4.1	+ 0.9	+ 2.1	0.0	- 1.4	- 0.1	+ 6.0	+ 2.1	- 3.5	- 1.8
1816.	+ 1.0	- 1.6	- 1.7	- 2.3	- 3.8	- 4.9	- 6.8	- 2.6	+ 2.6	+ 1.5	- 3.1	- 1.0
1817.	+ 3.5	+ 4.4	+ 0.7	- 1.8	- 4.7	+ 1.1	- 3.6	- 5.1	- 0.8	- 4.3	+ 4.5	- 1.7
1818.	+ 3.6	- 2.4	0.0	- 0.1	- 0.1	+ 4.9	+ 4.9	+ 3.1	+ 4.4	+ 4.4	+ 6.8	0.0
1819.	+ 4.4	+ 1.8	+ 3.1	+ 2.5	+ 1.6	- 1.6	+ 0.4	+ 3.3	+ 1.8	- 1.8	- 1.6	- 1.8
1820.	- 4.0	- 1.3	+ 0.4	+ 3.6	- 0.6	- 1.9	- 1.8	- 2.0	- 1.9	- 2.3	- 1.0	+ 1.1
1821.	+ 1.8	- 2.2	+ 1.9	+ 4.7	- 3.2	- 3.9	- 3.6	+ 1.2	+ 3.3	+ 1.0	+ 5.2	+ 5.5
1822.	+ 4.1	+ 5.1	+ 6.4	+ 1.0	+ 3.2	+ 4.6	+ 1.2	+ 0.8	- 0.3	+ 2.7	+ 5.8	- 2.4
1823.	- 3.9	- 0.1	- 1.1	- 2.9	+ 2.0	- 2.6	- 2.2	- 0.7	- 0.9	- 1.7	+ 0.6	+ 1.1
1824.	+ 1.7	- 2.0	- 1.4	- 1.9	- 3.1	- 3.0	+ 1.2	- 0.5	+ 1.4	+ 0.5	+ 3.8	+ 3.0
1825.	+ 2.7	- 0.1	- 2.4	+ 3.0	+ 1.0	+ 0.9	+ 3.9	+ 1.3	+ 3.6	+ 1.5	- 1.2	+ 1.8
1826.	- 3.7	+ 4.0	+ 2.3	+ 3.3	- 2.6	+ 4.9	+ 4.3	+ 2.9	0.0	+ 3.1	- 2.5	+ 3.0
1827.	- 2.3	- 6.6	+ 2.2	+ 1.1	+ 0.1	- 0.4	+ 2.2	- 1.5	+ 0.6	+ 2.5	- 0.9	+ 5.3
1828.	+ 4.1	+ 2.0	+ 2.6	+ 0.8	+ 1.7	+ 2.0	+ 0.6	- 1.5	+ 1.2	+ 0.6	+ 1.9	+ 5.7
1829.	- 4.0	+ 0.2	- 1.9	- 2.0	+ 1.9	+ 1.0	- 1.2	- 2.8	- 3.1	- 1.8	- 3.1	- 3.9
1830.	- 5.0	- 4.0	+ 4.9	+ 2.6	+ 2.1	- 2.7	+ 1.7	- 2.3	- 2.8	+ 1.6	+ 2.0	- 3.9
1831.	- 1.3	+ 3.0	+ 3.0	+ 2.4	+ 0.2	+ 1.4	+ 3.0	+ 2.8	+ 0.1	+ 5.7	+ 1.9	+ 3.2
1832.	+ 1.6	- 1.3	- 0.4	+ 1.5	- 1.1	+ 1.2	- 0.1	+ 0.5	+ 0.3	+ 1.9	+ 1.3	+ 3.6
1833.	- 1.2	+ 4.2	- 3.3	- 0.5	+ 6.8	+ 1.8	- 0.2	- 3.0	- 2.8	- 1.0	+ 1.1	+ 5.8
1834.	+ 8.7	+ 2.0	+ 3.1	- 0.7	+ 4.3	+ 3.1	+ 2.8	+ 1.8	+ 2.0	+ 1.2	+ 1.7	+ 2.2
1835.	+ 2.3	+ 3.0	+ 0.1	+ 0.7	+ 0.3	+ 2.0	+ 3.1	+ 2.8	+ 0.8	- 1.3	+ 0.6	- 3.9
1836.	+ 1.5	- 1.3	+ 2.8	- 2.4	+ 0.2	+ 1.0	+ 1.6	- 1.6	- 2.9	- 1.9	- 0.9	+ 0.8
1837.	+ 1.5	+ 2.1	- 5.1	- 6.6	- 4.8	+ 0.1	0.0	- 0.4	- 1.3	+ 1.3	- 1.3	+ 2.4
1838.	- 6.8	- 5.3	+ 0.6	- 4.1	- 1.9	- 0.8	- 0.8	- 0.9	- 1.9	+ 0.7	- 1.6	- 0.2
1839.	+ 1.5	+ 0.9	- 1.9	- 4.8	- 2.7	+ 0.7	- 1.1	- 1.6	- 0.7	- 0.4	+ 2.3	+ 0.8
1840.	+ 3.3	- 0.1	- 3.3	+ 2.1	+ 0.9	+ 1.5	- 3.3	+ 1.6	- 2.2	- 2.5	+ 1.0	- 5.5
1841.	- 2.1	- 2.9	+ 5.3	+ 1.5	+ 4.2	- 1.6	- 3.5	0.0	+ 1.8	- 0.5	+ 0.3	+ 1.7
1842.	- 2.8	+ 2.6	+ 4.0	- 0.5	+ 0.6	+ 4.9	- 1.1	+ 4.9	+ 0.1	- 3.9	+ 0.4	+ 6.2
1843.	+ 4.2	- 2.2	+ 2.0	+ 1.4	- 0.4	- 1.7	- 0.4	+ 1.6	+ 3.2	- 1.3	+ 1.4	+ 5.1
1844.	+ 3.4	- 3.0	+ 0.6	+ 6.0	+ 0.3	+ 2.7	+ 0.1	- 2.8	+ 0.6	+ 0.2	+ 1.6	- 5.8
1845.	+ 2.6	- 5.5	- 5.7	+ 0.6	- 3.2	+ 2.7	- 1.5	- 3.2	- 2.7	+ 0.9	+ 3.4	+ 2.9
1846.	+ 8.0	+ 5.7	+ 2.4	+ 1.4	+ 2.0	+ 7.3	+ 3.2	+ 2.7	+ 3.8	+ 1.2	+ 3.6	- 5.9
1847.	- 0.6	- 2.8	+ 0.1	- 0.4	+ 3.8	0.0	+ 4.1	+ 1.6	- 2.0	+ 3.6	+ 4.5	+ 4.0
1848.	- 1.1	+ 5.2	+ 2.9	- 1.9	+ 7.1	+ 0.5	+ 0.2	- 2.1	- 0.5	+ 2.3	+ 1.4	+ 5.2
1849.	+ 4.4	+ 5.0	+ 1.6	- 2.5	+ 1.4	- 0.1	+ 0.8	+ 2.4	+ 2.5	+ 1.8	+ 1.7	+ 0.3

The sign - denotes that the temperature of that month was below the average, and the sign + denotes that it was above the average.

By taking the means of the numbers in each column without respect to sign, we find that the variability of temperature is greatest in the winter months; its mean value in January is $3^{\circ}1$; in both February and March is $2^{\circ}6$; in April is $2^{\circ}3$; in May and June is $2^{\circ}0$; in the months of August, September and October, whose temperatures are the steadiest, it is $1^{\circ}9$; in November it is $2^{\circ}0$, and in December it is $3^{\circ}1$, as in January.

The numbers in the preceding Table very clearly show that causes exist at different times, which raise or depress the temperature, and which continue through long periods.

As in the distribution of the positive and negative signs in the space of seventy-nine years, we perceive a gradual increasing preponderance of the positive signs over the negative signs, it seems that the temperature of the climate during this period has increased.

As the mean results from so long a series of observations may be considered as true, having the advantage of being free from errors of observation and from those arising from imperfect instruments, we may really consider the numbers in the above Table as abnormal values; yet as it seems most desirable to have those at the beginning of the series confirmed by the description of each year, made without instrumental means, for this purpose, as well as for the comparison of the character of the climate at the beginning and at the end of the series, I have collected the following brief particulars of every year till that of 1800; after this time the general characters of the years are well known.

1771.—There were frequent and very sharp frosts till April 20. On February 12 the reading of the thermometer was as low as 4° ; the month of May was warm; the summer was cool and dry; October was a wet and windy month, and the weather was mild to the end of the year. The severe weather of the beginning of the year caused a bad seed time, and the harvest was very late.

1772.—The beginning of the year was mild; from the middle of January frosts and great snows were frequent, and continued to the middle of March. The summer was very fine; the autumn was mild but wet, and there was no frost till December 22.

1773.—With the exception of the latter part of February, which was stormy and wet, there was much fine weather till the beginning of May; then many mornings were frosty, after which heavy rain fell frequently till June. The summer was fine; the autumn was wet. There were sharp frosts at the end of November and at the beginning of December.

1774.—The year began with severe frost, and for nearly two months the ground was frost-bound; occasionally there were great rains or snow; the weather was more moderate in April; the summer was cool with heavy rains. The autumnal months were wet, particularly in September. Some snow fell in November and beginning of December. This year was remarkably wet.

1775.—The weather was mild at the beginning of the year. The summer was dry

and hot; thunder-storms were frequent in autumn. The year was very fine, and grain was cheaper than it had been for many years past.

1776.—In January there fell a greater quantity of snow than had fallen for some years, and the frost was supposed to have been the most severe since 1740. The frost went away at the beginning of February, and the weather following was mild and wet; it became hot about the middle of April. May was cold and dry, with north winds; after this the weather was mostly fine till the end of December, when there was a sharp frost.

1777.—The year began with a sharp frost, and heavy falls of snow continued till towards the end of February; for a few days about the end of March the weather was unusually hot, the reading of the thermometer being nearly 70° ; after this the weather was windy and cold till June. The latter part of the summer and autumn was fine. The year ended with frost and snow.

1778.—There were frost and snow at the beginning of the year; the beginning of April was fine. The summer was fine and hot, supposed at the time to have been as fine a summer as that of 1762, if not as fine as the summer of 1750. Frosty mornings began in September, but were less frequent afterwards. On the last day of this year there was a violent storm, supposed by some to have been as violent as that of 1703.

1779.—After the beginning of January there was no frost; the spring months were remarkably warm. In February wall fruit flowered; the middle of April was quite hot, as was the summer and autumn; about the middle of November there was a little frost, and again on December 22: there was much sickness this year.

1780.—This year began with a frost almost as severe as that in 1772; there was not much snow, and the weather continued severe till near the end of February. The month of March was warm; it was hot from July to September, and mostly mild till Christmas, when a frost set in. The year was sickly.

1781.—There was a little frost at the beginning of the year; the spring was mild, the summer was hot, and the ground was much burned. Autumn was fine and pleasant, and there were only a few frosty mornings during the remainder of the year.

1782.—The beginning of the year was mild, but in February it was frosty, and the remainder of the winter was severe; the spring was cold; nearly 12 inches of rain fell in April and May; the weather was fine in June, but bad afterwards; the autumn was cold; it was severe in November, and during the first half of December.

1783.—The spring was pleasant, with frosty mornings very constant till near April. A remarkable haze was prevalent all over Europe during the summer. The autumn was fine, and the weather was mostly mild till the last week in December, when a great fall of snow took place.

1784.—There was steady frost with snow till February 21, and till the end of March the mornings were frosty; and at the end of March there were cold winds with snow. This weather continued till the middle of April; and till the first week in May frosty mornings were frequent, and the remainder of May was exceedingly hot. There

were a few hot days in July, but the weather was precarious throughout the autumn ; and in December the frost was as severe as it was in January.

1785.—The severe frost of the preceding month broke early in January, but on the last day of that month a second very severe frost set in and continued till the middle of March. This winter was most severe. The summer and part of autumn were showery ; a heavy fall of snow took place at Christmas, with severe frost.

1786.—The frosts at the beginning of the year were of short duration. From the beginning of March there was a severe frost of a fortnight's duration, and cold E. and N.E. winds were prevalent with frosty mornings till the beginning of May. June and July were moderately fine ; August was cold and showery ; and from this time to the end of the year there was a great deal of rain.

1787.—The year began with open weather. April was cold with N. winds, and vegetation was stopped ; during April and May frosty mornings were frequent, and there was a sharp frost on the morning of the 7th of June ; it was a cold summer ; the autumn was mild, and there was a heavy fall of snow and a week's frost at the end of the year.

1788.—January and February were mild, the latter month being wet ; there was a fortnight's frost in March ; there were several periods of hot weather in April, May and June. The summer was in general dry ; autumn was fine ; there was a gentle frost at the beginning of December, then an exceedingly severe frost set in with heavy falls of snow, which continued to the end of the year. This year was remarkable for abundance of fruits, &c.

1789.—Very heavy storms of wind and snow took place till the middle of January ; and large rivers were frozen over ; there was a great loss of fish in ponds from the severity of the cold. After the frost broke the weather was mild, but windy and wet. During March there were nearly constant N. winds, and heavy falls of snow were frequent with sharp frost. The summer was mostly wet ; August was fine, after which it was again wet, and continued so to the end of the year, with scarcely any frost.

1790.—The weather was mild and open till April, when the first snow fell in the year, and the weather, during the beginning of this month, was the most severe during the winter. The summer was cool, cloudy and windy ; autumn was fine and pleasant ; December was stormy with very changeable weather.

1791.—Till January 6th there was frost ; after this the weather was mild till towards the end of April ; there were many frosty mornings with cold N.E. winds in May. The former part of the summer was cold ; frosty mornings were frequent till the middle of June, the latter part of summer and autumn. During November and December there were frequent storms and falls of snow and frost.

1792.—There were frequent sharp frosts till March, with stormy and wet weather ; the beginning of March was mild, after this there was a frost of a week's duration. The summer was wet and cold ; the autumn was wet, and December was cloudy, with very little frost. This year was very wet.

1793.—January and February and beginning of March were mild; a frost set in at the end of March; there was a great fall of snow in the first week in April. The former part of the summer was cold, with frequent frosty mornings till June; July was wet; the autumn was fine, mild and calm, and there was no frost till the end of the year.

1794.—The year began with slight frost, which continued till the end of January; February was very mild; the spring was warm till May, which was cold; July was hot; the autumn was wet but mild, as was the first part of December, but the weather during the latter half of the month was severe with heavy snow.

1795.—The frost began about the middle of December 1794, was excessively severe in January, and continued till the end of March. There were very large falls of snow, and the consequent floods were so great that nearly all the bridges in England were injured. Some snow fell in April. The summer was cold, with frequent frosty mornings till June; there were some hot days in July, but it was generally cold; after this the weather was fine till autumn. In December much injury was done to shipping by the strong S. and S.W. winds; there was no frost.

1796.—January was remarkably warm, with occasional thunder-storms; there was no frost till March, and then of no long duration. The summer was cool; the autumn was fine with a few frosty mornings at the end of November; in December a severe frost set in, and the reading of the thermometer in many places on the 24th was below zero of FAHRENHEIT's scale.

1797.—During a few days in January the frost continued; after this, till the end of March, scarcely any rain fell, and the weather was fine with frequent frost. From April to September there were frequent heavy rains. The summer was cold; there was some warm weather in July; the autumn in general fine, and the weather continued open till the end of the year.

1798.—With the exception of a few slight frosts, which occasionally occurred till March, the weather was open and mild. The summer was fine, as was autumn and the beginning of December; after this a very severe frost set in, and the reading of the thermometer was as low as 5°.

1799.—The severe frost which set in about the middle of the preceding month continued to the middle of January, and again set in towards the end of the month with much snow, which continued during the first week in February; some snow fell in March, and the mornings were frosty till the end of the month. From April to the middle of November was wet; December was foggy; and after the 17th a severe frost set in with snow falling. The whole year was remarkably cloudy.

If we compare the character of the preceding years with the abnormal differences shown for the same years in Table XX., the agreement is most satisfactory, and leaves no doubt upon the correctness of the numbers at the beginning of this series. I do not think it necessary to describe the years from that of 1800, as most of them are well described by LUKE HOWARD in his 'Climate of London.'

TABLE XXI.—Showing the mean temperature in quarterly periods, for the year, and the same for successive groups of years, at the Royal Observatory, Greenwich, from the year 1771 to 1849.

Year.	January, February, March.	Group of years.	April, May, June.	Group of years.	July, August, September.	Group of years.	October, November, December.	Group of years.	For the year.	Group of years.
1771.	32.7	37.6	49.1	52.0	56.6	59.6	43.2	43.6	45.4	48.2
1772.	35.0		50.1		58.2		45.1		47.1	
1773.	37.6		49.1		57.7		41.9		46.6	
1774.	37.4		52.7		58.9		41.7		47.7	
1775.	41.3		55.5		60.7		42.6		50.0	
1776.	36.9		52.2		59.3		44.8		48.3	
1777.	38.1		50.9		60.3		43.6		48.2	
1778.	36.8		54.3		61.3		44.5		49.2	
1779.	42.4		54.5		63.2		44.7		51.2	
1780.	37.7	36.8	52.9	52.0	62.7	59.0	42.0	41.0	48.8	47.2
1781.	39.7		53.9		61.7		43.7		49.8	
1782.	37.3		48.9		57.1		38.7		45.5	
1783.	37.9		51.5		60.3		42.2		48.0	
1784.	32.4		51.7		57.7		38.5		45.1	
1785.	33.5		52.7		58.8		40.8		46.5	
1786.	35.4		52.2		56.4		39.1		45.8	
1787.	39.7		51.2		59.0		42.6		48.1	
1788.	38.2		54.8		58.8		39.6		47.9	
1789.	35.9		50.7		57.9		42.4		46.7	
1790.	41.0	38.3	50.1	51.1	57.6	58.9	43.5	42.7	48.1	47.8
1791.	40.2		51.9		59.2		40.9		48.1	
1792.	38.1		51.0		58.7		44.0		48.0	
1793.	38.1		49.5		58.9		45.3		47.9	
1794.	40.8		52.6		59.5		42.8		48.9	
1795.	32.2		50.2		60.2		46.3		47.2	
1796.	41.3		51.5		59.2		39.1		47.8	
1797.	36.3		50.3		59.0		43.2		47.2	
1798.	38.8		54.7		59.7		41.2		48.6	
1799.	35.6		48.9		57.2		41.0		45.7	
1800.	36.2	38.7	52.5	52.1	61.6	60.0	42.8	43.5	48.3	48.5
1801.	40.7		52.5		60.6		42.4		49.0	
1802.	37.7		52.1		59.4		42.6		48.0	
1803.	37.3		51.4		59.3		44.7		48.2	
1804.	40.4		53.9		59.8		43.7		49.5	
1805.	38.4		49.9		60.0		42.3		47.7	
1806.	40.9		52.6		59.9		48.5		50.5	
1807.	37.9		52.6		60.1		42.8		48.3	
1808.	36.8		52.5		61.2		42.0		48.1	
1809.	40.7		51.4		58.2		43.4		48.0	
1810.	38.4	38.5	51.5	51.3	60.3	59.1	44.4	43.3	48.7	48.1
1811.	38.8		54.2		59.1		46.4		49.6	
1812.	38.6		48.9		56.8		41.5		46.5	
1813.	39.7		50.5		57.2		41.4		47.2	
1814.	32.0		50.0		58.2		43.0		45.8	
1815.	39.4		53.1		60.9		42.4		49.0	
1816.	37.5		48.4		57.1		42.6		46.4	
1817.	41.1		50.3		56.2		43.0		47.7	
1818.	38.7		53.7		63.5		47.2		50.8	
1819.	41.4		52.9		61.2		41.8		49.3	

TABLE XXI. (Continued.)

Year.	January, February, March.	Group of years.	April, May, June.	Group of years.	July, August, September.	Group of years.	October, November, December.	Group of years.	For the year.	Group of years.
1820.	36.6	38.4	52.5	52.5	57.5	59.6	42.8	44.7	47.4	48.8
1821.	38.8		51.3		59.7		47.4		49.3	
1822.	43.5		55.0		59.9		45.5		51.0	
1823.	36.6		50.9		58.1		43.5		47.3	
1824.	37.7		49.4		60.1		45.9		48.3	
1825.	38.3		53.7		62.3		44.2		49.6	
1826.	39.1		54.0		61.8		44.7		49.9	
1827.	36.0		52.4		59.8		45.8		48.5	
1828.	41.2		53.6		59.5		46.2		50.1	
1829.	36.4		52.4		57.0		40.6		46.6	
1830.	36.9	38.6	52.8	52.1	58.2	59.3	43.4	44.4	47.8	48.6
1831.	39.8		53.4		61.3		47.1		50.4	
1832.	38.2		52.6		59.6		45.8		49.1	
1833.	38.2		54.8		57.4		45.5		49.0	
1834.	42.9		54.3		61.6		45.2		51.0	
1835.	40.1		53.1		61.6		42.0		49.2	
1836.	39.3		51.7		58.4		42.8		48.1	
1837.	37.8		48.3		58.8		44.3		47.3	
1838.	34.4		49.8		58.2		43.1		46.4	
1839.	38.4		49.8		58.2		44.4		47.7	
1840.	38.2	39.3	53.6	53.6	58.1	59.7	41.2	44.4	47.8	49.2
1841.	38.4		53.5		58.8		44.0		48.7	
1842.	39.5		53.8		60.7		44.4		49.6	
1843.	39.6		51.9		60.8		45.2		49.4	
1844.	38.6		55.1		58.7		42.2		48.7	
1845.	35.4		52.1		56.9		45.9		47.6	
1846.	43.6		55.7		62.6		43.1		51.3	
1847.	37.2		53.2		60.6		47.5		49.6	
1848.	40.6		55.3		58.6		46.5		50.2	
1849.	41.9		51.7		61.3		44.8		49.9	

The mean temperature from all the observations

For the quarter ending March . 31 was 38.3,

„ June . 30 was 52.1,

„ September 30 was 59.4,

„ December 31 was 43.4,

and for the year from all the observations was 48°·29.

By taking the difference between these numbers, and those contained in the preceding Table, the next Table is immediately formed.

TABLE XXII.—Showing the excess of the quarterly and yearly mean temperatures, in every year, and the same for groups of years, above the means from all the years.

Year.	January, February, March.	Group of years.	April, May, June.	Group of years.	July, August, September.	Group of years.	October, November, December.	Group of years.	For the year.	Group of years.
1771.	-5.5	-0.7	-3.0	-0.1	-2.8	+0.2	-0.2	-0.2	-2.9	-0.1
1772.	-3.3		-2.0		-1.2		+1.7		-1.2	
1773.	-0.6		-3.0		-1.7		-1.5		-1.7	
1774.	-0.9		+0.6		-0.5		-1.7		-0.6	
1775.	+3.1		+3.4		+1.3		-0.8		+1.7	
1776.	-1.4		+0.1		-0.1		+1.4		0.0	
1777.	-0.1		-1.2		+0.9		+0.2		-0.1	
1778.	-1.5		+2.2		+1.9		+1.1		+0.9	
1779.	+4.2		+2.4		+3.8		+1.3		+2.9	
1780.	-0.6	-1.5	+0.8	0.0	+3.3	-0.4	-1.4	-2.4	+0.5	-1.1
1781.	+1.5		+1.8		+2.3		+0.3		+1.5	
1782.	-1.0		-3.2		-2.3		-4.7		-2.8	
1783.	-0.3		+0.4		+0.9		-1.2		-0.3	
1784.	-5.9		-0.4		-1.7		-4.9		-3.2	
1785.	-4.7		+0.8		-0.6		-2.6		-1.4	
1786.	-2.9		+0.1		-3.0		-4.3		-2.5	
1787.	+1.5		-0.9		-0.4		-0.8		-0.2	
1788.	0.0		+2.7		-0.6		-3.8		-0.4	
1789.	-2.4		-1.4		-1.5		-1.0		-1.6	
1790.	+2.8	0.0	-2.0	-1.0	-1.8	-0.5	+0.1	-0.7	-0.2	-0.5
1791.	+1.9		-0.2		-0.2		-2.5		-0.2	
1792.	-0.1		-1.1		-0.7		+0.6		-0.3	
1793.	-0.2		-2.6		-0.5		+1.9		-0.4	
1794.	+2.6		+0.5		+0.1		-0.6		+0.6	
1795.	-6.0		-1.9		+0.8		+2.9		-1.1	
1796.	+3.1		-0.6		-0.2		-4.3		-0.5	
1797.	-2.0		-1.8		-0.4		-0.2		-1.1	
1798.	+0.5		+2.6		+0.3		-2.2		+0.3	
1799.	-2.6		-3.2		-2.2		-2.4		-2.6	
1800.	-2.0	+0.4	+0.4	0.0	+2.2	+0.6	-0.6	+0.1	0.0	+0.3
1801.	+2.4		+0.4		+1.2		-1.0		+0.7	
1802.	-0.5		0.0		0.0		-0.8		-0.3	
1803.	-1.0		-0.7		-0.1		+1.3		-0.1	
1804.	+2.2		+1.8		+0.4		+0.3		+1.2	
1805.	+0.1		-2.2		+0.6		-1.1		-0.6	
1806.	+2.7		+0.5		+0.5		+5.1		+2.2	
1807.	-0.4		+0.5		+0.7		-0.6		0.0	
1808.	-1.4		+0.4		+1.8		-1.4		-0.2	
1809.	+2.4		-0.7		-1.2		0.0		-0.3	
1810.	+0.2	+0.2	-0.6	-0.8	+0.9	-0.4	+1.0	-0.1	+0.4	-0.2
1811.	+0.5		+2.1		-0.3		+3.0		+1.3	
1812.	+0.4		-3.2		-2.6		-1.9		-1.8	
1813.	+1.4		-1.6		-2.2		-2.0		-1.1	
1814.	-6.2		-2.1		-1.2		-0.4		-2.5	
1815.	+1.1		+1.0		+1.5		-1.0		+0.7	
1816.	-0.7		-3.7		-2.3		-0.8		-1.9	
1817.	+2.8		-1.8		-3.2		-0.4		-0.6	
1818.	+0.5		+1.6		+4.1		+3.8		+2.5	
1819.	+3.1		+0.8		+1.8		-1.6		+1.0	

TABLE XXII. (Continued.)

Year.	January, February, March.	Group of years.	April, May, June.	Group of years.	July, August, September.	Group of years.	October, November, December.	Group of years.	For the year.	Group of years.
1820.	-1.6	+0.2	+0.4	+0.4	-1.9	+0.2	-0.6	+1.3	-0.9	+0.5
1821.	+0.5		-0.8		+0.3		+4.0		+1.0	
1822.	+5.3		+2.9		+0.5		+2.1		+2.7	
1823.	-1.7		-1.2		-1.3		+0.1		-1.0	
1824.	-0.5		-2.7		+0.7		+2.5		0.0	
1825.	0.0		+1.6		+2.9		+0.8		+1.3	
1826.	+0.9		+1.9		+2.4		+1.3		+1.6	
1827.	-2.3		+0.3		+0.4		+2.4		+0.2	
1828.	+3.0		+1.5		+0.1		+2.8		+1.8	
1829.	-1.9		+0.3		-2.4		-2.8		-1.7	
1830.	-1.3	+0.4	+0.7	0.0	-1.2	-0.1	0.0	+1.0	-0.5	+0.3
1831.	+1.5		+1.3		+1.9		+3.7		+2.1	
1832.	0.0		+0.5		+0.2		+2.4		+0.8	
1833.	-0.1		+2.7		-2.0		+2.1		+0.7	
1834.	+4.7		+2.2		+2.2		+1.8		+2.7	
1835.	+1.8		+1.0		+2.2		-1.4		+0.9	
1836.	+1.1		-0.4		-1.0		-0.6		-0.2	
1837.	-0.5		-3.8		-0.6		+0.9		-1.0	
1838.	-3.8		-2.3		-1.2		-0.3		-1.9	
1839.	+0.1		-2.3		-1.2		+1.0		-0.6	
1840.	0.0	+1.0	+1.5	+1.5	-1.3	+0.3	-2.2	+1.0	-0.5	+1.0
1841.	+0.1		+1.4		-0.6		+0.6		+0.4	
1842.	+1.3		+1.7		+1.3		+1.0		+1.3	
1843.	+1.3		-0.2		+1.4		+1.8		+1.1	
1844.	+0.4		+3.0		-0.7		-1.2		+0.4	
1845.	-2.9		0.0		-2.5		+2.5		-0.7	
1846.	+5.4		+3.6		+3.2		-0.3		+3.0	
1847.	-1.1		+1.1		+1.2		+4.1		+1.3	
1848.	+2.3		+3.2		-0.8		+3.1		+1.9	
1849.	+3.6		-0.4		+1.9		+1.4		+1.6	

The sign — denotes that the temperature of that period was below the average, and the sign + denotes that it was above the average.

These numbers do not at all confirm the idea that a hot summer is either preceded or followed by a cold winter, or *vice versa*; on the contrary, it would seem that any hot or cold period has been mostly accompanied by weather of the same character. The cold year of 1771 was followed by two cold years. The hot year of 1779 was preceded by one warm year and followed by two others. In 1780 the extreme cold of January was more than counterbalanced by the extreme heat of March. The cold year of 1782 was followed by a long series of cold years. The very cold year of 1799 was followed by a cold autumn and winter. The warm year of 1806 was preceded by a warm winter. The very cold year of 1814 (the last very cold year we have had) was preceded by a cold summer, autumn and winter. The hot year of 1818 was preceded by a moderate winter, and was followed by a warm one. The hot year of 1822 was preceded by a warm winter and was followed by a moderately cold one. The hot year of 1834 followed a very mild winter and was followed by another. The hot

year of 1846 was preceded by a warm winter and was followed by a moderate one. The warm year 1848 was both preceded and followed by warm periods.

The mean temperatures of the years 1771, 1782, 1784, 1786, 1799 and 1814, were all below 46° ; the coldest was 1784, and its value was $45^{\circ}1$.

The mean temperatures of the years 1779, 1818, 1822, 1834 and 1846, were all above $50^{\circ}5$; the year of highest temperature was 1846, and its value was $51^{\circ}3$.

Thus seventy-nine years, from 1771 to 1849 inclusive, gives a mean temperature of $48^{\circ}3$, with a variation, between one year and another, from $45^{\circ}1$ in 1784 to $51^{\circ}3$ in 1846; the difference is $6^{\circ}2$.

TABLE XXIII.—Showing the mean temperature of the Air in Spring, Summer, Autumn, Winter, and for the year from March, and the same for successive groups of years.

Year.	Spring.		Summer.		Autumn.		Winter.		The year from March.	
	March, April, May.	Group of years.	June, July, August.	Group of years.	September, October, November.	Group of years.	December, January, February.	Group of years.	Whole year.	Group of years.
1771.	42.6	46.4	57.3	60.5	46.7	49.0	35.9	36.9	45.6	48.2
1772.	43.1		59.7		50.3		37.1		47.5	
1773.	44.2		58.3		47.1		35.9		46.4	
1774.	46.9		60.7		47.6		39.8		48.7	
1775.	48.5		62.1		48.9		35.4		48.8	
1776.	47.2		60.7		49.6		36.6		48.5	
1777.	47.0		59.7		51.0		35.4		48.3	
1778.	47.3		63.9		48.0		41.0		50.0	
1779.	50.8		62.3		51.5		34.7		49.8	
1780.	49.6	45.5	62.7	60.0	49.6	47.5	37.7	36.3	49.9	47.3
1781.	47.3		63.6		49.0		38.1		49.5	
1782.	42.5		57.9		45.1		37.4		45.7	
1783.	44.6		61.6		48.7		32.0		46.7	
1784.	45.0		57.3		47.3		32.5		45.5	
1785.	44.2		59.8		48.0		35.8		46.9	
1786.	43.7		59.2		44.2		37.4		46.1	
1787.	46.2		60.1		47.5		38.6		48.1	
1788.	48.1		59.7		48.5		34.1		47.6	
1789.	43.9		57.9		46.7		40.5		47.3	
1790.	45.6	45.8	58.6	59.1	48.5	48.8	39.2	37.0	48.0	47.7
1791.	46.8		59.5		48.2		35.7		47.6	
1792.	46.9		58.4		49.1		38.3		48.2	
1793.	44.1		59.8		49.2		39.7		48.2	
1794.	48.2		60.8		48.4		31.6		47.2	
1795.	45.2		57.8		51.6		43.2		49.5	
1796.	45.8		58.2		48.6		33.8		46.6	
1797.	44.6		59.0		47.7		39.0		47.6	
1798.	47.8		61.3		48.8		34.5		48.1	
1799.	42.7		57.6		48.2		34.6		45.8	
1800.	46.6	46.5	60.7	60.3	49.3	49.2	38.7	38.3	48.8	48.6
1801.	47.7		60.5		49.9		36.0		48.5	
1802.	46.6		59.6		49.0		35.8		47.7	
1803.	46.7		60.5		47.7		41.1		49.0	
1804.	47.1		60.5		51.6		36.3		48.9	
1805.	45.6		58.4		48.9		40.5		48.4	
1806.	46.2		60.8		51.9		41.2		50.0	
1807.	45.8		61.6		48.3		36.6		48.1	
1808.	45.6		62.1		48.4		38.5		48.7	
1809.	46.5		58.7		48.4		38.0		47.9	

TABLE XXIII. (Continued.)

Year.	Spring.		Summer.		Autumn.		Winter.		The year from March.	
	March, April, May.	Group of years.	June, July, August.	Group of years.	September, October, November.	Group of years.	December, January, February.	Group of years.	Whole year.	Group of years.
1810.	46.1	46.1	60.0	58.6	51.3	50.0	37.2	37.2	48.6	48.0
1811.	49.4		59.0		52.9		38.6		50.0	
1812.	43.7		56.1		48.4		37.0		46.3	
1813.	46.4		57.5		47.3		32.5		45.9	
1814.	43.9		57.7		47.6		38.1		46.8	
1815.	48.8		59.4		50.9		36.8		49.0	
1816.	43.8		55.2		49.7		39.9		47.1	
1817.	44.5		57.4		49.1		37.4		47.1	
1818.	46.3		64.2		54.5		39.6		51.2	
1819.	48.8		60.6		48.8		35.2		48.4	
1820.	47.5	47.1	58.0	60.0	47.6	50.0	37.8	38.0	47.7	48.8
1821.	47.5		57.8		52.6		42.5		50.1	
1822.	49.9		62.1		52.1		35.4		49.9	
1823.	45.7		58.0		48.7		37.8		47.6	
1824.	44.3		59.2		51.2		39.4		48.5	
1825.	46.9		62.0		50.6		38.3		49.5	
1826.	47.4		63.9		49.5		35.6		49.1	
1827.	47.5		60.0		50.1		41.4		49.8	
1828.	48.1		60.3		50.6		38.2		49.3	
1829.	45.7		58.9		46.7		33.3		46.2	
1830.	49.6	46.3	58.8	60.5	49.6	49.5	36.8	38.5	48.7	48.7
1831.	48.3		62.3		51.9		38.7		50.3	
1832.	46.4		60.5		50.5		39.8		49.3	
1833.	47.4		59.5		48.4		43.1		49.6	
1834.	48.6		62.5		51.0		40.1		50.5	
1835.	46.8		62.6		49.4		36.3		48.8	
1836.	46.6		60.3		47.4		39.0		48.3	
1837.	40.9		59.8		48.9		34.3		46.0	
1838.	44.6		59.1		48.4		38.3		47.6	
1839.	43.3		59.3		49.7		38.9		47.8	
1840.	46.3	47.7	59.9	60.7	48.1	50.1	34.1	38.5	47.1	49.3
1841.	50.1		58.2		49.9		38.1		49.1	
1842.	47.8		62.8		48.2		40.3		49.8	
1843.	47.4		59.8		50.4		39.4		49.3	
1844.	48.7		59.9		50.1		34.7		48.4	
1845.	43.6		59.3		49.9		43.1		49.0	
1846.	48.3		64.3		52.2		34.5		49.8	
1847.	47.6		61.8		51.4		40.3		50.2	
1848.	50.3		59.5		50.4		42.4		50.7	
1849.	46.6		61.0		51.3		39.2		49.5	

The mean temperature from all the results for Spring is 46.4

The mean temperature from all the results for Summer is 60.0

The mean temperature from all the results for Autumn is 49.3

The mean temperature from all the results for Winter is 37.6

The mean temperature from all the results for the Year is 48.3

The mean temperature of spring, from all the observations, is 46°.4.

The years distinguished by cold springs were 1771, 1772, 1782, 1786, 1789, 1799,

1812, 1814, 1816, 1837, 1839 and 1845, and the mean of their temperatures was $43^{\circ}1$.

The coldest spring, during the whole period, was in the year 1837, and its mean temperature was $40^{\circ}9$.

The years distinguished by hot springs were 1779, 1780, 1811, 1822, 1830, 1841 and 1848, and the mean of their temperatures was $50^{\circ}0$.

The hottest spring, during the whole period, was 1779, and its mean temperature was $50^{\circ}8$.

The mean temperature of summer, from all the observations, is $60^{\circ}0$. The years distinguished by cold summers were 1771, 1784, 1799, 1812, 1813, 1814, 1816, 1817, and the mean of their temperatures was $56^{\circ}9$.

The years distinguished by hot summers were 1778, 1779, 1780, 1781, 1818, 1826, 1831, 1834, 1835, 1842 and 1846, and the mean of their temperatures was $63^{\circ}2$. The coldest summer within the period was that in the year 1816, and its mean temperature was $55^{\circ}2$. The hottest summer within the period was that in the year 1846, and its mean temperature was $64^{\circ}3$.

The mean temperature of autumn, from all the observations, is $49^{\circ}3$. The years distinguished by cold autumns were 1771, 1782, 1786, 1789 and 1829, and the mean of their temperatures was $45^{\circ}9$.

The years distinguished by hot autumns were 1779, 1795, 1804, 1806, 1811, 1818, 1821, 1822, 1831 and 1846, and the mean of their temperatures was $52^{\circ}3$. The coldest autumn within the period was that in the year 1786, and its mean temperature was $44^{\circ}2$. The hottest autumn within the period was that in the year 1718, and its mean temperature was $54^{\circ}5$.

The mean temperature of winter, from all the observations, was $37^{\circ}6$. The years distinguished by cold winters were 1783, 1784, 1794, 1796, 1813 and 1829; the mean of their temperatures was $32^{\circ}6$.

The years distinguished by warm winters were 1778, 1795, 1803, 1806, 1821, 1827, 1833, 1845 and 1848, and the mean of their temperatures was $42^{\circ}1$.

The coldest winter within the period was that in the year 1794, and its mean temperature was $31^{\circ}6$.

The warmest winter within the period was that in the year 1795, and its mean value was $43^{\circ}2$. The winters of the years 1833 and 1845 were remarkably warm, being both of the value of $43^{\circ}1$.

By taking the difference between the mean temperature of each period from all the observations, and the mean temperature for the same period, in every year, the next Table is formed.

TABLE XXIV.—Showing the excess of the mean temperature, in every year, in Spring, Summer, Autumn, Winter, and the Year, above the mean temperature for each period from all the years, and the same for groups of years.

Year.	Spring.		Summer.		Autumn.		Winter.		The year from March.	
	March, April, May.	Group of years.	June, July, August.	Group of years.	September, October, November.	Group of years.	December, January, February.	Group of years.	Whole year.	Group of years.
1771.	-3.8	0.0	-2.7	+0.5	-2.6	-0.3	-1.7	-0.7	-2.7	-0.1
1772.	-3.3		-0.3		+1.0		-0.5		-0.8	
1773.	-2.2		-1.7		-2.1		-1.7		-1.9	
1774.	+0.5		+0.7		-1.7		+2.2		+0.4	
1775.	+2.1		+2.1		-0.3		-2.2		+0.5	
1776.	+0.8		+0.7		+0.3		-1.0		+0.2	
1777.	+0.6		-0.3		+1.8		-2.2		0.0	
1778.	+0.9		+3.9		-1.3		+3.4		+1.7	
1779.	+4.4		+2.3		+2.3		-2.9		+1.5	
1780.	+3.2	-0.9	+2.7	0.0	+0.3	-1.8	+0.1	-1.3	+1.6	-1.0
1781.	+0.9		+3.6		-0.2		+0.5		+1.2	
1782.	-3.9		-2.1		-4.2		-0.2		-2.6	
1783.	-1.8		+1.6		-0.5		-5.6		-1.6	
1784.	-1.4		-2.7		-2.0		-5.1		-2.8	
1785.	-2.2		-0.2		-1.2		-1.8		-1.4	
1786.	-2.7		-0.8		-5.1		-0.2		-2.2	
1787.	-0.2		+0.1		-1.7		+1.0		-0.2	
1788.	+1.7		-0.3		-0.8		-3.5		-0.7	
1789.	-2.5		-2.1		-2.5		+2.9		-1.0	
1790.	-0.8	-0.6	-1.4	-0.9	-0.8	-0.4	+1.6	-0.6	-0.3	-0.6
1791.	+0.4		-0.5		-1.0		-1.9		-0.7	
1792.	+0.5		-1.6		-0.2		+0.7		-0.1	
1793.	-2.3		-0.2		0.0		+2.1		-0.1	
1794.	+1.8		+0.8		-0.9		-6.0		-1.1	
1795.	-1.2		-2.2		+2.4		+5.6		+1.2	
1796.	-0.6		-1.8		-0.7		-3.8		-1.7	
1797.	-1.8		-1.0		-1.5		+1.4		-0.7	
1798.	+1.4		+1.3		-0.5		-3.1		-0.2	
1799.	-3.7		-2.4		-1.0		-3.0		-2.5	
1800.	+0.2	+0.1	+0.7	+0.3	+0.1	-0.1	+1.1	+0.5	+0.5	+0.3
1801.	+1.3		+0.5		+0.6		-1.6		+0.2	
1802.	+0.2		-0.4		-0.3		-1.8		-0.6	
1803.	+0.3		+0.5		-1.6		+3.5		+0.7	
1804.	+0.7		+0.5		+2.4		-1.3		+0.6	
1805.	-0.8		-1.6		-0.3		+2.9		+0.1	
1806.	-0.2		+0.8		+2.6		+3.6		+1.7	
1807.	-0.6		+1.6		-0.9		-1.0		-0.2	
1808.	-0.8		+2.1		-0.9		+0.9		+0.4	
1809.	+0.1		-1.3		-0.8		+0.4		-0.4	
1810.	-0.3	-0.3	0.0	-1.4	+2.1	+0.8	-0.4	-0.4	+0.3	-0.3
1811.	+3.0		-1.0		+3.6		+1.0		+1.7	
1812.	-2.7		-3.9		-0.8		-0.6		-2.0	
1813.	0.0		-2.5		-2.0		-5.1		-2.4	
1814.	-2.5		-2.3		-1.6		+0.5		-1.5	
1815.	+2.4		-0.6		+1.6		-0.8		+0.7	
1816.	-2.6		-4.8		+0.5		+2.3		-1.2	
1817.	-1.9		-2.6		-0.2		-0.2		-1.2	
1818.	-0.1		+4.2		+5.3		+2.0		+2.9	
1819.	+2.4		+0.6		-0.5		-2.4		+0.1	

TABLE XXIV. (Continued.)

Year.	Spring.		Summer.		Autumn.		Winter.		The year from March.	
	March, April, May.	Group of years.	June, July, August.	Group of years.	September, October, November.	Group of years.	December, January, February.	Group of years.	Whole year.	Group of years.
1820.	+1.1	} +0.7	-2.0	} 0.0	-1.6	} -0.7	+0.2	} +0.4	-0.6	} +0.5
1821.	+1.1		-2.2		+3.3		+4.9		+1.8	
1822.	+3.5		+2.1		+2.9		-2.2		+1.6	
1823.	-0.7		-2.0		-0.6		+0.2		-0.7	
1824.	-2.1		-0.8		+2.0		+1.8		+0.2	
1825.	+0.5		+2.0		+1.3		+0.7		+1.2	
1826.	+1.0		+3.9		+0.3		-2.0		+0.8	
1827.	+1.1		0.0		+0.8		+3.8		+1.5	
1828.	+1.7		+0.3		+1.4		+0.6		+1.0	
1829.	-0.7		-1.1		-2.6		-4.3		-2.1	
1830.	+3.2	} +0.1	-1.2	} +0.5	+0.4	} -0.2	-0.8	} +0.9	+0.4	} +0.4
1831.	+1.9		+2.3		+2.6		+1.1		+2.0	
1832.	0.0		+0.5		+1.3		+2.2		+1.0	
1833.	+1.0		-0.5		-0.9		+5.5		+1.3	
1834.	+2.2		+2.5		+1.8		+2.5		+2.2	
1835.	+0.4		+2.6		+0.1		-1.3		+0.5	
1836.	+0.2		+0.3		-1.8		+1.4		0.0	
1837.	-5.5		-0.2		-0.4		-3.3		-2.3	
1838.	-1.8		-0.9		-0.8		+0.7		-0.7	
1839.	-3.1		-0.7		+0.4		+1.3		-0.5	
1840.	-0.1	} +1.3	-0.1	} +0.7	-1.1	} +0.8	-3.5	} +0.9	-1.2	} +1.0
1841.	+3.7		-1.8		+0.6		+0.5		+0.8	
1842.	+1.4		+2.8		-1.0		+2.7		+1.5	
1843.	+1.0		-0.2		+1.1		+1.8		+1.0	
1844.	+2.3		-0.1		+0.9		-2.9		+0.1	
1845.	-2.8		-0.7		+0.6		+5.5		+0.7	
1846.	+1.9		+4.3		+3.0		-3.1		+1.5	
1847.	+1.2		+1.8		+2.1		+2.7		+1.9	
1848.	+3.9		-0.5		+1.2		+4.8		+2.4	
1849.	+0.2		+1.0		+2.0		+1.6		+1.2	

The sign — denotes that the temperature of that period was below the average, and the sign + denotes that it was above the average.

By taking the mean of the numbers for each period, without regard to gauge,

The mean variability in Spring is . . . 1.6

The mean variability in Summer is . . . 1.5

The mean variability in Autumn is . . . 1.4

The mean variability in Winter is . . . 2.2

The mean variability in the Year is . . . 1.1

All the following Tables are based upon the readings of self-registering thermometers, and exhibit the extreme readings at the Apartments of the Royal Society, and at the Royal Observatory, Greenwich. The first process in their formation was the copying from the Philosophical Transactions every reading of these thermometers, arranging all the minimum readings one under the other, and all the maximum readings similarly under each other, and then taking their monthly mean readings, or otherwise as was necessary to the construction of the Tables.

TABLE XXV.—Showing the monthly mean reading of the minimum temperature, and during the whole time that the maximum and minimum self-registering thermometer, at the Royal Observatory, Greenwich.

Year.	January.		February.		March.		April.		May.		June.	
	Mean of all the		Mean of all the		Mean of all the		Mean of all the		Mean of all the		Mean of all the	
	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.
1794.	32.0	38.5	43.6	49.5	40.6	51.4	45.8	58.9	46.5	60.1	52.3	67.7
1795.	23.0	29.7	32.8	39.0	35.6	45.3	42.4	53.3	46.3	62.1	50.9	63.3
1796.	43.8	50.8	37.9	45.9	35.3	46.6	43.1	57.9	45.5	59.7	51.2	66.7
1797.	34.7	40.0	38.9	42.9	34.3	45.7	41.0	53.7	45.7	62.0	49.2	65.9
1798.	36.1	43.2	35.2	44.8	37.5	48.1	44.1	59.5	49.0	63.7	55.2	72.2
1799.	32.1	38.5	33.8	42.9	35.0	44.0	39.1	49.1	45.5	59.0	50.5	65.7
1800.	35.7	41.7	33.1	40.7	34.7	44.1	45.6	56.0	50.9	64.3	51.1	64.7
1801.	37.1	45.0	36.8	43.9	41.1	50.7	39.8	55.8	47.2	63.3	52.7	68.9
1802.	31.2	37.4	37.0	44.7	36.7	49.6	43.3	58.6	54.0	61.8	51.6	67.6
1803.	33.1	37.5	34.6	42.0	38.8	50.3	43.9	57.3	46.7	59.4	52.3	65.5
1804.	41.8	47.8	35.3	43.1	38.4	47.8	45.3	51.7	52.4	66.8	55.1	71.8
1805.	33.6	38.9	36.5	44.9	38.4	49.4	41.4	54.6	45.0	59.6	50.2	65.3
1806.	38.8	46.0	39.3	47.5	39.0	46.5	40.3	50.8	49.9	65.1	54.2	70.9
1807.	35.5	42.8	37.4	46.2	34.0	44.6	44.7	55.8	51.1	64.2	52.5	68.2
1808.	35.2	42.5	34.1	42.5	35.2	43.3	39.1	51.4	52.2	67.8	53.8	68.8
1809.	33.8	40.3	41.8	50.0	39.6	49.9	38.0	49.7	50.2	65.2	53.3	68.2
1810.	33.6	39.0	37.3	43.7	39.2	49.1	42.2	54.9	45.2	59.7	52.7	70.0
1820.	30.5	37.9	35.3	43.0	37.2	50.3	44.9	59.5	48.3	62.7	52.5	66.2
1821.	35.6	43.7	33.5	43.4	39.6	50.6	45.4	58.7	44.9	60.5	50.2	63.6
1822.	35.8	46.0	40.5	50.7	44.0	55.5	43.9	55.3	52.6	65.0	58.8	73.6
1823.	.....	.....	.....	.....	.....	.....	.....	.....	49.7	64.2	49.9	66.4
1824.	36.6	41.7	37.7	43.8	37.3	45.7	40.7	51.6	46.5	58.5	51.1	64.6
1825.	37.3	43.3	36.7	44.2	36.4	45.2	44.1	58.6	48.5	63.1	51.9	69.7
1826.	29.8	37.3	40.4	47.9	.....	.....	44.6	58.8	46.3	60.8	56.4	74.6
1827.	31.2	39.2	29.3	37.5	40.1	49.7	43.3	55.3	49.1	61.6	52.8	67.5
1828.	37.5	45.0	38.4	45.2	40.0	51.0	43.1	55.0	50.0	64.2	55.9	70.2
1829.	30.1	36.3	36.4	43.7	35.9	45.7	40.6	52.4	48.4	64.9	54.1	69.6
1830.	29.3	35.0	30.9	40.5	41.5	53.9	44.1	57.9	50.0	64.8	52.0	65.2
1831.	32.5	38.9	38.5	47.2	40.9	50.8	45.1	57.2	47.1	63.0	54.7	69.0
1832.	34.5	40.8	34.7	42.6	36.9	47.7	42.0	56.4	46.3	61.6	55.2	69.5
1833.	32.8	39.0	39.6	48.1	34.6	44.3	41.7	54.7	52.9	70.4	54.5	70.6
1834.	42.5	49.0	36.7	46.6	40.4	51.3	40.3	54.4	50.5	67.7	55.0	72.5
1835.	35.3	43.1	37.1	47.7	37.1	48.3	42.4	55.8	48.0	62.5	54.6	70.7
1836.	34.5	43.8	34.0	42.3	40.2	50.5	40.5	51.3	44.7	60.6	55.2	69.1
1837.	35.3	42.7	38.0	46.5	33.9	42.6	37.3	47.0	44.4	57.6	53.8	68.5
1838.	27.1	34.4	31.2	38.4	38.1	49.2	39.2	50.9	45.8	61.3	53.6	68.6
1839.	34.7	43.3	37.1	47.7	37.4	44.2	39.7	46.0	45.0	60.5	54.9	70.2
1840.	36.9	43.5	36.5	42.4	35.9	41.7	43.3	53.5	49.6	.....	55.5	71.2
1841.	32.7	40.3	34.9	40.8	42.7	55.4	48.2	56.4	52.4	68.0	52.2	69.7
1842.	32.0	38.1	38.4	46.4	41.6	51.5	41.1	53.8	48.8	64.9	58.3	76.6
1843.	37.7	45.7	34.9	41.6	39.6	50.0	44.0	57.9	48.2	64.3	51.9	67.6
At the Royal Observatory, Greenwich.												
1840.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1841.	28.4	39.5	31.6	40.7	38.7	56.2	39.9	56.4	48.4	69.7	48.2	67.0
1842.	29.3	36.6	36.0	46.6	39.2	51.8	37.3	54.7	45.0	64.5	52.2	75.2
1843.	35.4	44.7	31.9	40.2	37.5	50.5	40.7	57.9	45.5	63.3	49.0	67.0
1844.	34.1	43.9	30.9	41.6	35.7	48.9	41.8	63.6	45.1	65.9	51.6	74.1
1845.	34.3	43.3	27.9	38.4	30.8	42.4	39.3	57.5	42.7	59.6	52.2	72.5
1846.	39.4	48.1	39.3	49.0	38.1	51.6	41.8	56.4	47.4	66.7	55.1	80.4
1847.	31.5	40.1	30.5	41.5	34.3	50.1	36.8	55.4	47.5	68.0	49.7	69.4
1848.	29.8	38.1	38.0	48.7	36.4	50.7	39.0	57.2	43.4	75.4	38.7	78.4
1849.	35.7	45.2	36.5	49.4	36.3	50.1	36.5	52.5	46.7	63.8	48.5	69.1

the monthly mean reading of the maximum temperature of Air as observed daily, meters were in use at the Apartments of the Royal Society, and from 1840, No-

Year.	July.		August.		September.		October.		November.		December.	
	Mean of all the		Mean of all the		Mean of all the		Mean of all the		Mean of all the		Mean of all the	
	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.	Minimum readings.	Maximum readings.
1794.	59.9	78.4	55.3	70.2	50.8	61.3	46.9	55.0	41.6	49.1	35.3	40.1
1795.	53.0	66.1	56.6	71.7	55.6	70.4	51.0	60.3	38.2	46.9	43.2	48.9
1796.	53.7	68.7	54.4	70.9	54.6	67.4	44.3	52.9	38.9	45.1	28.4	35.7
1797.	56.5	75.8	53.8	70.0	50.4	63.5	44.3	53.8	38.8	48.0	38.7	46.3
1798.	55.8	71.7	57.8	73.6	52.5	65.1	47.0	57.0	37.8	45.3	32.2	38.0
1799.	55.6	69.1	53.4	67.7	49.9	63.0	45.0	54.7	41.1	48.0	32.3	36.3
1800.	57.1	74.7	57.6	75.2	54.1	66.1	44.8	55.4	39.9	48.1	37.1	42.0
1801.	55.1	70.9	57.4	73.4	55.3	67.0	47.7	57.7	38.5	45.8	34.3	41.5
1802.	51.3	66.9	58.5	76.3	52.0	68.5	46.3	58.7	39.1	45.7	35.8	43.0
1803.	58.4	70.7	56.5	72.6	46.9	63.8	46.3	56.2	39.7	47.7	40.2	45.4
1804.	57.9	69.7	56.3	70.0	55.3	68.5	48.4	58.9	42.7	48.8	34.8	39.7
1805.	55.1	69.1	58.0	72.0	54.9	68.6	45.0	53.9	37.6	45.6	37.5	44.3
1806.	57.1	70.9	57.2	71.9	53.0	66.1	48.4	58.0	45.5	53.1	44.8	50.7
1807.	59.0	74.3	60.0	73.7	48.7	61.4	50.2	60.2	36.9	45.0	34.7	41.4
1808.	59.8	76.9	58.4	72.5	52.1	63.8	43.2	53.8	42.3	49.1	35.2	40.6
1809.	55.6	69.4	59.5	69.4	53.0	64.6	47.2	56.3	37.5	45.1	38.8	45.3
1810.	55.8	70.7	55.9	70.8	55.2	68.0	47.7	58.8				
1820.	56.3	68.8	55.7	69.8	49.7	64.1	44.2	55.5	39.8	48.1	38.5	45.3
1821.	54.0	67.3	58.2	71.3	56.4	67.7	47.0	58.8	44.3	54.0	41.0	50.6
1822.	59.3	70.6	58.7	69.9	53.2	64.1	50.3	58.6	47.1	54.1	34.5	41.3
1823.	55.4	67.7	56.9	68.6	51.2	64.1	45.0	53.9	42.0	46.8	38.9	44.0
1824.	57.4	72.1	56.9	69.1	54.9	65.1	47.5	56.3	43.2	51.4	39.6	46.3
1825.	59.9	74.5	57.5	71.0	57.7	68.0	48.7	56.9	38.3	46.4	39.2	43.9
1826.	.....	.....	61.2	73.6	54.3	65.3	50.3	59.4	38.3	45.5	40.8	45.7
1827.	58.1	73.4	55.2	68.8	54.2	65.0	49.2	58.5	39.5	48.0	41.0	49.1
1828.	58.3	71.5	55.9	68.6	54.2	66.4	46.2	57.0	41.8	49.9	42.6	49.2
1829.	56.2	69.8	55.2	66.6	50.3	61.6	46.8	58.9	36.7	44.9	31.4	36.6
1830.	58.1	73.0	53.9	68.5	50.1	62.0	47.0	58.4	41.9	49.7	32.2	39.4
1831.	58.3	76.6	59.9	73.2	52.9	65.2	53.1	61.6	39.3	49.1	40.6	46.0
1832.	56.1	71.2	56.8	71.3	51.8	66.2	48.4	57.9	41.9	49.0	39.0	47.0
1833.	56.1	71.5	53.0	68.4	49.4	62.5	46.9	58.1	40.4	49.1	40.8	50.3
1834.	59.3	74.7	57.9	72.8	54.1	67.3	46.2	58.2	41.4	49.4	38.1	45.6
1835.	57.3	74.8	58.4	73.8	52.8	65.8	45.4	54.5	41.5	47.5	33.6	39.6
1836.	57.1	71.9	54.5	68.9	50.3	61.2	45.3	52.5	38.7	47.6	38.0	44.4
1837.	56.7	71.7	56.6	70.0	51.7	63.2	46.1	58.8	37.2	49.0	39.8	46.0
1838.	56.0	70.8	56.4	69.0	51.5	62.6	47.0	57.4	38.9	46.8	37.5	43.5
1839.	56.7	69.9	55.4	68.6	53.0	63.5	47.3	54.3	43.8	48.0	38.0	41.8
1840.	54.9	69.8	57.9	72.7	50.0	63.3	43.2	54.8	40.8	50.7	31.5	38.8
1841.	54.8	68.8	57.2	70.0	51.7	67.3	47.0	56.9	40.8	49.8	38.8	47.1
1842.	55.5	73.5	60.8	76.0	53.5	65.6	42.9	53.4	41.5	49.0	41.9	50.5
At the Royal Observatory, Greenwich.												
1840.	.....	.....	.....	.....	.....	.....	.....	.....	35.7	46.7	27.1	36.1
1841.	51.5	67.1	54.3	70.6	51.2	67.2	43.9	55.6	38.0	48.7	35.4	44.8
1842.	52.1	71.2	56.3	78.1	49.8	64.3	39.3	53.4	39.0	48.1	40.2	49.4
1843.	53.5	71.8	55.2	72.5	52.3	70.4	42.0	55.5	38.5	50.0	40.3	48.2
1844.	54.1	72.8	50.3	67.9	50.2	67.5	44.4	56.7	39.6	48.1	30.4	36.8
1845.	53.5	71.2	50.5	67.7	46.9	63.9	44.0	59.0	40.3	51.8	35.8	47.6
1846.	56.5	77.9	56.6	74.4	51.4	71.9	44.5	58.7	40.0	50.3	27.9	37.2
1847.	54.8	78.1	52.8	74.4	46.1	64.9	46.4	01.5	40.8	52.7	37.2	46.7
1848.	51.2	73.7	50.4	68.9	45.9	66.8	43.8	59.2	36.1	50.5	37.3	48.9
1849.	51.6	74.2	54.0	74.2	51.2	68.7	44.1	59.2	38.1	49.8	34.1	43.3

TABLE XXVI.—Showing the highest and lowest readings by the self-registering were in use at the Apartments of the Royal Society, and at the Royal Observatory,

Year.	January.		February.		March.		April.		May.		June.	
	Reading of the thermo- meters in the month.		Reading of the thermo- meters in the month.		Reading of the thermo- meters in the month.		Reading of the thermo- meters in the month.		Reading of the thermo- meters in the month.		Reading of the thermo- meters in the month.	
	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.
1794.	22	51	35	56	34	56	38	73	40	71	46	79
1795.	7	46	24	51	24	54.5	36	61	36	81.5	41	77.5
1796.	36	56	30	56	26.5	60	36	70	39	65	45	80
1797.	25	49	24.5	50	27.5	54	34	65	34	79	40	73
1798.	28	53	24	54	30	58	30	69	43	76	47	86
1799.	20	50	18	56	28	56	27	59	36	70	43	77
1800.	18	51	25	53	23	57	38	62	40	75	43	75
1801.	24	54	25	57	31	59	30	67	39	71	43	80
1802.	15	48	29	56	27	65	33	68	31	76	40	78
1803.	19	48	19	53	25	66	36	72	38	69	49	74
1804.	27	55	25	51	28	62	34	71	44	73	47	87
1805.	25	48	23	54	29	62	35	64	37	72	41	75
1806.	28	55	30	56	26	56	31	64	43	75	46	83
1807.	23	51	25	57	25	55	31	77	44	84	48	77
1808.	18	53	18	53	26	54	27	64	42	82	48	76
1809.	20	55	34	57	33	62	29	57	36	78	45	78
1810.	14	51	18	54	28	59	31	69	34	67	45	78
1820.	20	53	26	52	28	66	36	67	39	70	45	85
1821.	25	52	25	61	31	58	36	72	37	70	43	73
1822.	31	51	34	54	35	66	35	64	45	75	50	84
1823.	24	.....	.....	.....	.....	.....	.....	.....	40	75	43	74
1824.	25	52.5	28	52	28	56	28	66.5	42	73	43	74
1825.	30	54	26	51	28	53	34	66	40	71.5	42	81
1826.	16	47	32	54	.....	.....	.....	.....	36.5	72.5	49.8	87.5
1827.	16	48.8	19	52.5	31.2	57.6	32.8	73.5	37.8	69.8	46.3	74.5
1828.	28	54.5	29	55.2	29.1	61.3	32.8	70.7	42.7	72.1	49.3	78.4
1829.	19.5	45.7	23.2	50.8	26.8	58.6	30.7	59.3	44.3	70.6	41.1	77.8
1830.	17.2	42.7	17.7	56.3	32.7	65.7	29.7	72.0	42.6	77.3	46.6	76.7
1831.	24.3	48.5	26.7	59.5	31.7	59.4	35.3	65.2	33.8	72.6	48.6	75.7
1832.	27.8	48.7	28.3	49.6	30.7	55.3	36.7	67.0	38.4	74.7	46.8	76.7
1833.	27.3	46.6	32.4	55.2	27.8	54.2	34.0	62.4	43.4	81.4	46.6	80.8
1834.	32.5	55.2	29.3	54.7	30.7	57.8	33.2	64.3	43.0	75.0	47.3	86.7
1835.	25.0	49.7	27.9	53.2	32.7	54.2	30.0	66.2	41.7	72.8	44.6	83.6
1836.	17.5	53.4	25.3	50.6	31.8	64.4	32.2	61.3	35.3	69.5	47.7	82.6
1837.	24.0	50.7	30.0	54.0	26.7	49.0	28.0	59.2	35.5	68.6	43.2	75.8
1838.	11.4	50.2	24.8	48.7	31.0	58.3	29.8	64.2	36.2	73.3	44.2	79.7
1839.	23.7	51.8	26.8	51.3	26.0	53.2	30.5	58.7	33.7	72.2	45.6	85.0
1840.	22.3	54.2	27.8	50.8	30.7	53.7	34.4	72.2	41.3	.....	48.3	83.0
1841.	14.9	52.8	21.6	52.2	35.0	64.2	36.7	72.4	45.3	79.4	45.3	87.0
1842.	27.3	44.6	32.0	53.0	33.6	58.5	34.2	69.3	41.8	78.3	52.7	83.6
1843.	29.8	57.7	23.8	53.0	30.5	61.0	33.0	66.0	40.3	73.4	47.3	79.7
At the Royal Observatory, Greenwich.												
1840.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1841.	4.0	53.0	12.4	54.6	29.5	66.9	31.8	76.5	41.2	82.8	40.3	78.5
1842.	23.2	46.8	26.4	53.2	29.9	60.5	28.0	73.7	36.4	74.7	44.7	87.4
1843.	24.0	57.0	20.3	51.9	26.5	63.7	27.2	70.8	37.3	69.5	42.9	77.3
1844.	18.8	53.7	20.0	50.4	24.1	60.2	33.4	74.9	33.9	77.4	43.4	87.6
1845.	24.4	51.3	7.7	48.5	13.1	59.4	29.5	70.3	34.4	68.2	43.8	86.0
1846.	29.4	55.3	26.9	62.3	26.5	58.0	33.3	63.0	38.3	84.3	49.4	91.1
1847.	23.0	52.7	10.2	55.0	16.9	64.2	27.0	63.8	36.0	86.2	41.0	80.4
1848.	15.8	50.4	29.2	55.0	27.3	71.5	29.7	75.0	33.5	83.0	38.7	78.4
1849.	20.0	56.4	26.8	58.0	27.7	60.7	28.6	64.3	36.8	75.0	38.6	80.7

By comparing the readings of the two places for the years 1841, 1842 and 1843, it grees below those at the Apartments of the Royal Society. In January 1841 the the difference is wholly attributable to the effect of the comparative heated water of places at some distance from and those near the river. The maximum temperatures 1841 at Somerset House I think must be erroneous.

maximum and minimum thermometers in each month during the whole time they Greenwich, from the year 1841 to 1849.

Year.	July.		August.		September.		October.		November.		December.	
	Reading of the thermometers in the month.		Reading of the thermometers in the month.		Reading of the thermometers in the month.		Reading of the thermometers in the month.		Reading of the thermometers in the month.		Reading of the thermometers in the month.	
	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.
1794.	54	84	48	78	37	68	35	63	30.5	57	25.5	54
1795.	46	76	51	79	45	78	42	68	28	56	34	56
1796.	44.5	77.5	48	80	45	79	30	59	29	57	4	51
1797.	48	85	48	76	42	71	35	63	27	57	29	56
1798.	51	78	52	83	44	76	32	64	25	60	11	50
1799.	48	77	47	73	42	72	35	63	32	58	17	50
1800.	50	81	49	89	41	77	35	66	30	59	29	51
1801.	47	79	51	79	46	73	34	66	26	60	23	52
1802.	45	71	50	82	40	75	33	75	30	53	29	50
1803.	51	86	47	81	38	75	38	67	31	57	21	55
1804.	49	80	49	81	45	81.5	38	68	34	59	19	51
1805.	50	79	51	79	43	79	35	63	31	55	25	54
1806.	52	81	51	80	44	73	35	65	36	60	39	57
1807.	48	85	52	80	38	72	39	68	28	56	23	51
1808.	50	93.5	51	80	39	71	35	63	31	56	19	53
1809.	50	78	49	79	40	72	35	65	29	54	32	54
1810.	51	78	50	80	48	83	30	68				
1820.	50	80	46	77	38	73	39	65	31	56	25	57
1821.	46	74	50	77	46	75	41	68	34	63	36	58
1822.	53	76	50	80	45	70	41	66	38	61	23	54
1823.	49	74	49	78	40	73	37	62	29	55	29	53
1824.	51	81	50.5	77	37	81	31	65	29	60	31	54
1825.	51	89	53	84	47	77	33	68	29	58	28	53.5
1826.	.....	.....	55	81.2	43.8	72.3	37.6	67.8	26.8	52.3	32.2	53
1827.	51.8	81.1	48.3	80.2	47.7	70.0	36.4	67.7	23.8	55.8	30.8	54.8
1828.	46.8	78.7	49.8	72.7	44.9	72.8	36.5	63.3	25.7	58.4	33.8	55.3
1829.	48.7	74.7	46.7	76.5	42.4	66.7	33.3	61.4	26.8	52.7	18.2	46.0
1830.	48.8	85.8	46.0	77.7	43.8	69.8	35.2	66.5	33.0	58.5	15.8	47.2
1831.	52.3	80.8	54.4	79.7	46.5	72.2	40.3	68.2	28.7	57.2	29.8	55.6
1832.	49.6	81.2	47.0	81.8	41.6	72.9	39.4	68.2	36.3	59.3	32.3	55.8
1833.	47.3	80.5	48.2	75.3	41.0	67.2	38.3	62.3	31.6	59.7	32.9	55.6
1834.	51.4	86.7	46.2	85.3	46.8	74.0	34.4	70.2	33.2	61.5	29.2	54.5
1835.	50.6	84.2	51.8	80.6	46.4	76.3	35.4	62.6	34.9	55.5	21.0	51.6
1836.	46.2	85.2	48.4	73.4	40.7	69.6	30.0	61.2	31.3	56.7	27.4	55.7
1837.	47.5	79.6	48.5	78.8	44.4	69.7	35.4	68.5	28.0	56.4	31.7	55.3
1838.	49.6	79.0	46.5	76.0	42.8	69.5	32.8	63.5	30.0	57.7	29.8	55.0
1839.	48.6	80.3	45.4	78.6	45.0	70.0	37.3	63.5	33.8	55.3	32.0	54.6
1840.	49.4	77.2	52.4	80.0	41.7	75.7	35.3	60.7	30.3	60.6	21.2	55.5
1841.	49.8	80.3	50.0	77.5	42.8	74.6	37.2	64.3	28.2	58.6	29.9	55.8
1842.	50.4	82.7	50.0	87.0	44.4	76.0	34.0	60.7	35.6	55.5	34.7	57.5
At the Royal Observatory, Greenwich.												
1840.	.....	.....	.....	.....	.....	.....	.....	.....	23.8	61.2	16.4	55.2
1841.	44.3	76.0	45.5	79.6	36.6	79.6	32.2	64.6	22.2	58.3	24.3	53.9
1842.	45.5	78.8	47.5	90.5	41.1	75.8	28.3	60.9	31.1	55.9	30.8	58.2
1843.	44.6	89.8	47.2	82.8	34.0	79.9	28.5	70.4	27.4	57.5	25.6	54.7
1844.	47.1	87.4	42.8	75.4	34.8	78.0	30.8	67.4	27.4	58.1	21.1	49.3
1845.	44.6	83.3	43.2	77.8	33.4	73.5	31.4	67.6	29.1	59.6	28.0	55.5
1846.	49.1	93.3	47.5	92.0	39.2	86.4	35.0	67.7	23.4	61.5	18.8	49.9
1847.	45.4	89.0	42.0	87.3	32.0	72.5	33.0	73.2	24.5	66.3	25.0	59.5
1848.	42.2	85.3	42.5	75.5	32.8	78.8	32.4	74.0	25.2	57.8	21.8	62.8
1849.	47.0	84.1	42.4	82.5	42.7	79.0	31.5	69.7	23.5	61.7	18.8	56.3

will be seen that the minimum temperatures at the Observatory are usually some de-reading at the Observatory was as low as 4°, whilst that at Somerset House was 14°·9; the Thames, and this difference is always shown at those low temperatures between at the Observatory are usually the higher, but not always so; the maximum in June

TABLE XXVII.—Showing the extreme readings of the thermometer in every year that self-registering thermometers were used at the Royal Society's Apartments, and from the year 1840 to 1849 at the Royal Observatory, Greenwich.

Year.	At the Apartments of the Royal Society.				
	Highest reading of the thermometer.	Lowest reading of the thermometer.	Difference or range of reading in the year.	Month and day of	
				Highest readings.	Lowest readings.
1794.	84.0	22.0	62.0	On July 13.	On January 10.
1795.	81.5	7.0	74.5	On May 23.	On January 25.
1796.	80.0	4.0	76.4	On June 26 and August 22.	On December 25.
1797.	85.0	24.5	60.5	On July 14.	On February 28.
1798.	86.0	11.0	75.0	On June 28.	On December 29.
1799.	77.0	17.0	60.0	On June 10, 30, July 6 and 8.	On December 31.
1800.	89.0	18.0	71.0	On August 2.	On January 1.
1801.	80.0	23.0	57.0	On June 29.	On December 20.
1802.	82.0	15.0	67.0	On August 30.	On January 16.
1803.	86.0	19.0	67.0	On July 2.	On January 26 and February 11.
1804.	87.0	19.0	68.0	On June 25.	On December 24.
1805.	79.0	23.0	56.0	On July 4, August 12 and Sept. 18.	On February 2.
1806.	83.0	26.0	57.0	On June 10.	On March 13.
1807.	85.0	23.0	62.0	On July 22.	On January 15 and December 8.
1808.	93.5	18.0	75.5	On July 13.	On January 22 and February 15.
1809.	79.0	20.0	59.0	On August 17.	On January 18 and 19.
1810.	83.0	14.0	69.0	On September 2.	On January 17.
1820.	85.0	20.0	65.0	On June 27.	On January 5.
1821.	77.0	25.0	52.0	On August 5, 6, 22, 24 and 25.	On January 2, 3 and February 27.
1822.	84.0	23.0	61.0	On June 10.	On December 30.
1823.	78.0	24.0	49.0	On August 13.	On January 15.
1824.	81.0	25.0	56.0	On July 13, 14 and September 1.	On January 14.
1825.	89.0	26.0	63.0	On July 19.	On February 5.
1826.	87.5	16.0	71.5	On June 27.	On January 16.
1827.	81.1	16.0	65.1	On July 29.	On January 3.
1828.	78.7	25.7	53.0	On July 3.	On November 12.
1829.	77.8	18.2	59.6	On June 3.	On December 28.
1830.	85.8	15.8	70.0	On July 30.	On December 25.
1831.	80.8	24.3	56.5	On July 29.	On January 8.
1832.	81.8	27.8	54.0	On August 10.	On January 5.
1833.	81.4	27.3	54.1	On May 15.	On January 23.
1834.	86.7	29.2	57.5	On June 21 and July 17.	On December 24.
1835.	84.2	21.0	63.2	On July 28.	On December 25.
1836.	85.2	17.5	67.7	On July 4.	On January 2.
1837.	79.6	24.0	55.6	On July 28.	On January 2.
1838.	79.7	11.4	68.3	On June 24.	On January 16.
1839.	85.0	23.7	61.3	On June 20.	On January 30.
1840.	83.0	21.2	61.8	On June 1.	On December 18.
1841.	87.0	14.9	72.1	On June 20.	On January 9.
1842.	87.0	27.3	59.7	On August 11.	On January 24.
At the Royal Observatory, Greenwich.					
1841.	82.8	4.0	78.8	On May 27.	On January 9.
1842.	90.5	23.2	67.3	On August 10.	On January 23.
1843.	89.8	20.3	69.5	On July 6.	On February 15.
1844.	87.6	18.8	68.6	On June 25.	On January 3.
1845.	86.0	7.7	78.3	On June 13.	On February 11.
1846.	93.3	18.8	74.5	On July 5.	On December 14 and 30.
1847.	89.0	10.2	78.8	On July 12.	On February 11.
1848.	85.3	15.8	69.5	On July 14.	On January 28.
1849.	84.1	18.8	65.3	On July 8.	On December 29.

From the particulars in this Table, it seems that the highest reading of the thermometer within the year has occurred three times in May, seventeen times in June, twenty-four times in July, ten times in August, and three times in September.

The lowest reading of the thermometer in the year has occurred twenty-eight times in January, nine times in February, once in March, once in November, and fourteen times in December.

TABLE XXVIII.—Showing the highest and lowest temperature during the period in each month.

Month.	At the Apartments of the Royal Society.					At the Royal Observatory, Greenwich.				
	The lowest reading of the thermometer.	The highest reading of the thermometer.	Difference of readings.	Mean of all the		The lowest reading of the thermometer.	The highest reading of the thermometer.	Difference of readings.	Mean of all the	
				Lowest readings.	Highest readings.				Lowest readings.	Highest readings.
January ...	7·0	57·7	50·7	22·6	51·0	4·0	57·0	53·0	20·2	52·9
February...	17·7	61·0	43·3	26·1	53·7	7·7	62·3	54·6	19·9	54·3
March.....	23·0	66·0	43·0	29·2	58·5	13·1	71·5	58·4	24·6	62·7
April	27·0	77·0	50·0	32·8	66·5	27·0	76·5	49·5	29·8	70·3
May	31·0	84·0	53·0	39·3	73·8	33·5	86·2	52·7	36·4	77·9
June	40·0	87·5	47·5	45·5	79·5	38·6	87·6	49·0	42·5	83·0
July.....	44·5	93·5	49·0	49·3	80·5	42·2	93·3	51·1	45·5	85·2
August ...	45·4	89·0	43·6	49·4	79·3	42·0	92·0	50·0	44·5	82·6
September	37·0	83·0	46·0	42·9	73·6	32·0	86·4	54·4	36·3	78·2
October ...	30·0	75·0	45·0	35·5	65·2	28·3	74·0	45·7	31·4	68·4
November	23·8	63·0	39·2	30·4	57·4	22·2	66·3	44·1	26·0	59·6
December	4·0	58·0	54·0	25·9	53·6	16·4	62·8	46·4	23·5	55·5

The lowest reading, as observed at the Apartments of the Royal Society, was 4°; it occurred in the night of December 24, 1796 (at this time the reading in the environs of London was—6°). The highest reading was 89°; the difference of these readings is 85°.

The lowest reading, as observed at the Royal Observatory within the years 1841 to 1849, was 4°, and the highest was 93°·3; the difference of these readings is 89°·3.

TABLE XXIX.—Showing the extreme range of the thermometer in every month during the time self-registering instruments were in use at the Apartments of the Royal Society, and at the Royal Observatory, Greenwich, from 1840.

Year.	At the Apartments of the Royal Society.											
	Extreme range of readings of the thermometer in each month.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1794.	29	21	22	35	31	33	30	30	31	28	26.5	28.5
1795.	39	27	30.5	25	45.5	36.5	30	28	33	26	28	22
1796.	20	26	33.5	34	26	35	33	32	34	29	28	47
1797.	24	25.5	26.5	31	45	33	37	28	29	28	30	27
1798.	25	30	28	39	33	39	27	31	32	32	35	39
1799.	30	38	28	32	34	34	29	26	30	28	26	33
1800.	33	28	34	24	35	32	31	40	36	31	29	22
1801.	30	32	28	37	32	37	32	28	27	32	34	29
1802.	33	27	38	35	45	38	26	32	35	42	23	21
1803.	29	34	41	36	31	25	35	34	37	29	26	34
1804.	28	26	34	37	29	40	31	32	36.5	30	25	32
1805.	23	31	33	29	35	34	29	28	36	28	24	29
1806.	27	26	30	33	32	37	29	29	29	30	24	18
1807.	28	32	30	46	40	29	37	28	34	29	28	28
1808.	35	35	28	37	40	28	43.5	29	32	28	25	34
1809.	35	23	29	28	42	33	28	30	32	30	25	22
1810.	37	36	31	38	33	33	27	30	35	38		
1820.	33	26	38	31	31	40	30	31	35	26	25	32
1821.	27	36	27	36	33	30	28	27	29	27	29	22
1822.	20	20	31	29	30	34	23	30	25	25	23	31
1823.	.....	.....	.....	.....	35	31	25	29.0	33	25	26	24
1824.	27.5	24	28	38.5	31	31	30	26.5	44	34	31	23
1825.	24	25	25	32	31.5	39	38	31.0	30	35	29	25.5
1826.	31	22	.....	.....	36	37.7	.....	26.2	28.5	30.2	25.5	20.8
1827.	32.8	33.5	26.4	40.7	32	28.2	29.3	31.9	22.3	31.3	32.0	24.0
1828.	26.5	26.2	32.2	37.9	29.4	29.1	31.9	22.9	27.9	26.8	32.7	21.5
1829.	26.2	27.6	31.8	28.6	26.3	36.7	26.0	29.8	24.3	28.1	25.9	27.8
1830.	25.5	38.6	33.0	42.3	34.7	30.1	37.0	31.7	26.0	31.3	25.5	31.4
1831.	24.2	32.8	27.7	29.9	38.8	27.1	28.5	25.3	25.7	27.9	28.5	25.8
1832.	20.9	21.3	24.6	30.3	36.3	29.9	31.6	34.8	31.3	28.8	23.0	23.5
1833.	19.3	22.8	26.4	28.4	38.0	34.2	33.2	27.1	26.2	24.0	28.1	22.7
1834.	22.7	25.4	27.1	31.1	32.0	39.4	35.3	39.1	27.2	35.8	28.3	25.3
1835.	24.7	25.3	21.5	36.2	31.1	39.0	33.6	28.8	29.9	27.2	20.6	30.6
1836.	35.9	25.3	32.6	29.1	34.2	34.9	39.0	25.0	28.9	31.2	25.4	28.3
1837.	26.7	24.0	22.3	31.2	33.1	32.6	32.1	30.3	25.3	33.1	28.4	23.6
1838.	38.8	23.9	27.3	34.4	37.1	35.5	29.4	29.5	26.7	30.7	27.7	25.2
1839.	28.1	24.5	27.2	28.2	38.5	39.4	31.7	33.2	25.0	26.2	21.5	22.6
1840.	31.9	23.0	23.0	37.8	.....	34.7	27.8	27.6	34.0	25.4	30.3	34.3
1841.	37.9	30.6	29.2	35.7	34.1	41.7	30.5	27.5	31.8	27.1	30.4	25.9
1842.	17.3	21.0	24.9	35.1	36.5	30.9	32.3	37.0	31.6	26.7	19.9	22.8
1843.	27.9	29.2	30.5	33.0	33.1	32.4						
At the Royal Observatory, Greenwich.												
1840.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	37.4	38.8
1841.	49.0	42.2	37.4	44.7	41.6	38.2	31.7	34.1	43.0	32.4	36.1	29.6
1842.	23.6	26.8	30.6	45.7	38.3	42.7	33.3	43.0	34.7	32.6	24.8	27.4
1843.	33.0	31.6	37.2	43.6	32.2	34.4	45.2	35.6	45.9	41.9	30.1	29.1
1844.	34.9	30.4	36.1	41.5	43.5	44.2	40.3	32.6	43.2	36.6	30.7	28.2
1845.	26.9	40.8	46.3	40.8	33.8	42.2	38.7	34.6	40.1	36.2	30.5	27.5
1846.	25.9	35.4	31.5	29.7	46.0	41.7	44.2	44.5	47.2	32.7	38.1	31.1
1847.	29.7	44.8	47.3	36.8	50.2	39.4	43.6	45.3	40.5	40.2	41.8	34.5
1848.	34.6	25.8	44.2	45.3	49.5	39.7	43.1	33.0	46.0	41.6	32.6	41.0
1849.	36.4	31.2	33.0	35.7	38.2	42.1	37.1	40.1	36.3	38.2	38.2	35.9

TABLE XXX.—Showing the mean daily range of temperature in each month.

Year.	At the Apartments of the Royal Society.											
	The average daily range of temperature.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1794.	8.5	5.9	10.8	13.1	13.6	15.4	16.5	14.9	10.5	9.1	7.5	4.8
1795.	6.7	6.2	9.7	10.9	15.8	12.4	13.1	15.1	14.8	9.3	8.7	5.7
1796.	7.0	8.0	11.3	14.8	14.2	15.5	15.0	16.5	12.8	8.6	6.2	7.3
1797.	5.3	4.0	11.4	12.7	16.3	16.7	19.3	16.2	13.1	9.0	9.2	7.6
1798.	7.1	9.6	10.6	15.4	14.7	17.6	15.9	15.8	12.6	10.0	7.5	5.8
1799.	6.4	9.1	9.0	10.0	13.5	15.2	13.5	14.3	13.1	9.7	6.9	4.0
1800.	6.0	7.6	9.4	10.4	13.4	13.6	17.6	17.6	12.0	10.6	8.2	4.9
1801.	7.9	7.1	9.6	16.0	16.1	16.2	15.8	16.0	11.7	10.0	7.3	7.2
1802.	6.2	7.7	12.9	15.3	7.8	16.0	15.6	17.8	16.5	12.4	6.6	7.2
1803.	4.4	7.4	11.5	13.4	12.7	13.2	12.3	16.1	16.9	9.9	8.0	5.2
1804.	6.0	7.3	9.4	6.4	14.4	16.7	11.8	13.7	13.2	10.5	6.1	4.9
1805.	5.3	8.4	11.0	13.2	14.6	15.1	14.0	14.0	13.7	8.9	8.0	6.8
1806.	7.2	8.2	7.5	10.5	15.2	16.7	13.8	14.7	13.1	9.6	7.6	5.9
1807.	7.3	8.8	10.6	11.1	13.1	15.7	15.3	13.7	12.7	10.0	8.1	6.7
1808.	7.3	8.4	8.1	12.3	15.5	14.5	17.1	14.1	11.7	10.6	6.8	5.4
1809.	6.5	8.2	10.3	11.7	15.0	15.9	13.8	9.9	11.6	9.1	7.6	6.5
1810.	5.4	6.5	9.9	12.7	14.5	17.3	14.9	14.9	12.8	11.1	.....	.....
1820.	7.4	7.7	13.1	14.6	14.4	13.7	12.5	14.1	14.4	11.3	8.3	6.8
1821.	8.1	9.9	11.0	13.3	15.6	13.4	13.3	13.1	11.3	11.8	9.7	9.6
1822.	10.2	10.2	11.5	11.4	12.4	15.3	11.3	11.2	10.9	8.3	7.0	6.8
1823.	.....	.....	.....	.....	14.5	16.5	12.3	11.7	12.9	8.9	4.8	5.1
1824.	5.1	6.1	8.4	10.9	12.0	13.5	14.7	12.2	10.2	8.8	8.2	6.7
1825.	6.0	7.5	8.8	14.5	14.6	17.8	14.6	13.5	10.3	8.2	8.1	4.7
1826.	7.5	7.5	.....	14.2	14.5	18.2	.....	12.4	11.0	9.1	7.2	4.9
1827.	8.0	8.2	9.6	12.0	12.5	14.7	15.3	13.6	10.8	9.3	8.5	8.1
1828.	7.5	6.8	11.0	11.9	14.2	14.3	13.2	12.7	12.2	10.8	8.1	6.6
1829.	6.2	7.3	9.8	11.8	16.5	15.5	13.6	11.4	11.3	8.1	8.2	5.2
1830.	5.7	9.6	12.4	13.8	14.8	13.2	14.9	14.6	11.9	11.4	7.8	7.2
1831.	6.4	8.7	9.9	12.1	15.9	14.3	18.3	13.3	12.3	8.5	9.8	5.4
1832.	6.3	7.9	10.8	14.4	15.3	14.3	15.1	14.5	14.4	9.5	7.1	8.0
1833.	6.2	8.5	9.7	13.0	17.5	16.1	15.4	15.4	13.1	11.2	8.7	9.5
1834.	6.5	9.9	10.9	14.1	17.2	17.5	15.4	14.9	13.2	12.0	8.0	7.5
1835.	7.8	10.6	11.1	13.4	14.5	16.1	17.5	15.4	13.0	9.1	6.0	6.0
1836.	9.3	8.3	10.3	10.8	15.9	13.7	14.8	14.4	10.9	8.2	8.9	6.4
1837.	7.4	8.5	8.7	9.7	13.2	14.7	15.0	13.4	11.5	12.7	11.8	6.8
1838.	7.3	7.2	11.1	11.7	15.5	15.0	14.8	12.6	11.1	10.4	7.9	6.0
1839.	8.6	10.6	6.8	6.3	15.5	15.3	13.2	13.2	10.5	7.0	4.2	3.8
1840.	6.6	5.9	5.8	10.2	.....	15.7	14.9	14.8	13.3	11.6	9.9	7.3
1841.	7.6	5.9	12.7	13.2	15.6	17.5	14.0	12.8	15.6	9.9	9.0	8.3
1842.	6.1	8.0	9.9	12.7	16.1	18.3	18.0	15.2	12.1	10.5	7.5	8.6
1843.	8.0	6.7	10.4	13.9	16.1	15.7	.....	.....	.....	.....	.....	.....
At the Royal Observatory, Greenwich.												
1840.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.0	9.0
1841.	11.1	9.1	17.5	16.5	21.3	18.8	15.6	16.3	16.0	11.7	10.7	9.4
1842.	6.4	10.4	10.9	16.1	16.7	22.2	17.7	20.3	12.8	13.2	7.9	8.2
1843.	7.9	7.5	12.4	15.4	14.7	15.2	15.6	16.4	17.4	12.8	10.2	6.6
1844.	8.7	10.5	12.1	21.0	18.6	19.9	16.2	15.4	15.3	12.4	7.4	5.4
1845.	6.4	8.7	11.1	16.8	14.2	18.2	14.9	14.8	15.6	13.3	10.9	9.9
1846.	7.7	8.3	12.7	13.1	16.6	22.5	17.5	15.5	18.0	10.4	8.0	10.3
1847.	8.8	11.6	16.0	18.3	21.2	19.4	23.3	21.0	18.7	14.0	11.4	9.7
1848.	8.3	10.7	14.3	16.7	30.5	17.7	22.5	18.5	20.9	16.5	15.7	12.7
1849.	10.8	12.9	13.8	16.0	16.3	20.6	22.6	20.2	17.5	15.1	11.7	9.1

TABLE XXXI.—Showing the mean monthly minimum temperature by night, the mean monthly maximum temperature by day, the mean daily and monthly range of temperature, at the Apartments of the Royal Society, and at the Royal Observatory, Greenwich, together with the increase of temperature month by month, by night and by day.

Month.	Mean of all the mini- mum readings, or of the lowest temperature by night at the		Higher mean minimum reading at the Royal Society.	Mean of all the maxi- mum readings, or of the highest temperature by day at the		Lower mean maximum reading at the Royal Society.	The mean daily range of temperature at the		Less daily range at the Royal Society.	The mean monthly range of temperature at the		Less monthly range at the Royal Society.	Monthly increase in the mean									
	Royal Society.	Royal Ob- servatory.		Royal Society.	Royal Ob- servatory.		Royal Society.	Royal Ob- servatory.		Tempera- ture of the air.	At the Royal Society.		At the Royal Ob- servatory.	Of the lowest tempera- ture by night	Of the highest tempera- ture by day							
December ...	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
January	34.4	33.1	1.3	46.2	42.2	-3.0	6.8	8.5	1.7	28.4	32.7	4.8	-3.1	-1.5	-3.7	-1.8	-3.1	-1.5	-3.7	-1.8	-3.7	-1.8
February	36.4	33.6	2.8	44.3	44.0	-0.3	7.9	9.9	2.0	27.6	34.3	6.7	+2.5	+0.5	+3.1	+1.8	+2.5	+0.5	+3.1	+1.8	+3.1	+1.8
March	37.8	36.3	1.5	48.2	50.3	2.1	10.2	13.4	3.2	29.3	38.2	8.9	+2.7	+1.4	+3.7	+6.8	+2.7	+1.4	+3.7	+6.8	+3.7	+6.8
April	42.5	39.2	3.3	54.7	56.8	2.1	12.3	16.7	4.4	33.7	40.5	6.8	+4.8	+4.7	+2.9	+6.5	+4.8	+4.7	+2.9	+7.0	+6.5	+6.5
May	48.3	45.7	2.6	63.1	66.3	3.5	14.8	18.9	4.1	34.8	41.5	6.7	+6.9	+5.8	+6.5	+8.4	+6.9	+5.8	+6.5	+8.2	+8.4	+8.4
June	53.1	49.5	3.6	68.6	72.6	4.0	15.5	19.4	3.9	34.0	40.5	6.5	+5.4	+4.8	+3.8	+7.4	+5.4	+4.8	+3.8	+5.5	+7.4	+7.4
July	56.6	53.2	3.4	71.4	73.1	1.7	14.9	18.4	3.5	31.2	39.7	8.5	+3.3	+3.5	+3.7	+0.5	+3.3	+3.5	+3.7	+3.8	+0.5	+0.5
August	56.9	53.4	3.5	70.8	72.1	1.3	14.1	17.6	3.5	29.9	38.1	8.2	-0.8	0.0	+0.2	-1.0	-0.8	0.0	+0.2	-0.6	-1.0	-1.0
September ...	52.6	49.4	3.2	65.1	67.3	2.2	12.5	17.0	4.5	30.7	41.8	11.1	-4.2	-4.0	-4.0	-4.8	-4.2	-4.0	-4.0	-5.7	-4.8	-4.8
October	46.8	43.6	3.2	56.7	57.6	0.9	9.9	13.3	3.4	29.5	36.9	7.4	-7.0	-5.8	-5.8	-9.7	-7.0	-5.8	-5.8	-8.4	-9.7	-9.7
November ...	40.4	38.6	1.8	48.2	49.7	1.5	8.0	10.5	2.5	27.0	34.0	7.0	-6.9	-6.4	-4.9	-7.9	-6.9	-6.4	-4.9	-8.5	-7.9	-7.9
December ...	37.5	34.6	2.9	43.9	44.0	0.1	6.4	9.0	2.6	27.1	32.3	5.2	-3.6	-2.9	-4.1	-5.7	-3.6	-2.9	-4.1	-4.3	-5.7	-5.7

The successive differences shown here between the results at the Apartments of the Royal Society and at the Royal Observatory, are harmonious with the differences exhibited in Table XIII. and following remarks, between the temperatures of the water of the Thames and those of the air at Greenwich, but of less amount, and they indicate the great influence the presence of a tidal river has upon the meteorological elements of the district through which it passes.

The subjects of this paper are the determination of mean numerical values, and the establishment of the laws of periodic variation from the long series of observations which were taken under the direction of this Society, combined with that still being made at Greenwich. I have not attempted to deduce any rules for non-periodic variations.

It is most fortunate that through all reports this series of observations continued unbroken for so many years, and that it did not cease till that at Greenwich had been in operation for two or three years.

The number of observations treated of in this paper exceeds 200,000, spread nearly equally over seventy-nine years, and the results generally are important additions to science. I consider the determination of the mean temperature at Greenwich as a real addition; it is probably the best determination of this element of any spot on the globe, and it will help to an accurate knowledge of the mean temperature of its surface.

I may however here remark, that none of the mean results in this paper could have been calculated if observations at equal intervals had not been taken throughout the twenty-four hours and continued for a few years. The observations at Greenwich have supplied this want. It was upon them, taken for five years, I based my determinations of curve of hourly mean temperature, and by this means have made all the observations available.

As it is difficult to have instruments read more frequently than twice or thrice in a day, yet, to make these available, it is necessary that the laws of diurnal changes of temperature be known; and where such is not the case, an effort should be made in all countries to have a series of hourly or bi-hourly observations made for a few years, so as to be able to deduce useful results. Such series of frequent observations need not be made near each other, as it is found that the observations made over a considerable extent of country are subject to the same general laws.

XXX. *On the Dynamical Stability and on the Oscillations of Floating Bodies.*

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IF a body be made, by the action of certain disturbing forces, to pass from one position of equilibrium into another, and if in each of the intermediate positions these forces are in excess of the forces opposed to its motion, it is obvious that, by reason of this excess, the motion will be continually accelerated, and that the body will reach its second position with a certain finite velocity, whose effect (measured under the form of *vis viva*) will be to carry it beyond that position. This however passed, the case will be reversed, the resistances will be in excess of the moving forces, and the body's velocity being continually diminished and eventually destroyed, it will, after resting for an instant, again return towards the position of equilibrium through which it had passed. It will not however finally rest in this position until it has completed other oscillations about it. Now the amplitude of the first oscillation of the body beyond the position in which it is finally to rest, being its greatest amplitude of oscillation, involves practically an important condition of its stability; for it may be an amplitude sufficient to carry the body into its next adjacent position of equilibrium, which being, of necessity, a position of unstable equilibrium, the motion will be yet further continued and the body overturned. Different bodies requiring moreover different amounts of work to be done upon them to produce in all the same amplitude of oscillation, that is (relatively to that amplitude) the most stable which requires the greatest amount of work to be so done upon it. It is this condition of stability, dependent upon dynamical considerations, to which, in the following paper, the name of dynamical stability is given.

I cannot find that the question has before been considered in this point of view, but only in that which determines whether any given position be one of stable, unstable or mixed equilibrium; or which determines what pressure is necessary to retain the body at any given inclination from such a position.

1. To the discussion of the conditions of the dynamical stability of a body the principle of *vis viva* readily lends itself. That principle*, when translated into a language which the labours of M. PONCELET have made familiar to the uses of practical science, may be stated as follows:—

* See POISSON, *Mécanique*, chap. ix. Art. 565; PONCELET, *Mécanique Industrielle*, *passim*; *Mechanical Principles of Engineering* by the author of this paper, Art. 129.

“When, being acted upon by given forces, a body or system of bodies has been moved from a state of rest, the difference between the aggregate *work* of those forces whose tendencies are *in* the directions in which their points of application have been moved, and that of the forces whose tendencies are in the opposite direction, is equal to one-half the *vis viva* of the system.”

Thus, if Σu_1 be taken to represent the aggregate work of the forces by which a body has been displaced from a position in which it was at rest, and Σu_2 the aggregate work (during this displacement) of the other forces applied to it; and if the terms which compose Σu_1 and Σu_2 be understood to be taken positively or negatively, according as the tendencies of the corresponding forces are in the directions in which their points of application have been made to move or in the opposite directions; then representing the aggregate *vis viva* of the body by $\frac{1}{g} \Sigma wv^2$

$$\Sigma u_1 + \Sigma u_2 = \frac{1}{2g} \Sigma wv^2, \quad (1.)$$

Now Σu_2 representing the aggregate work of those forces which acted upon the body in the position from which it has been moved, may be supposed to be known; Σu_1 may therefore be determined in terms of the *vis viva*, or conversely.

2. In the extreme position into which the body is made to oscillate and from which it begins to return, it, for an instant, *rests*. In this position, therefore, its *vis viva* disappears, and we have

$$\Sigma u_1 + \Sigma u_2 = 0. \quad (2.)$$

This equation, in which Σu_1 and Σu_2 are functions of the impressed forces and of the inclination, determines the extreme position into which the body is made to roll by the action of given disturbing forces; or, conversely, it determines the forces by which it may be made to roll into a given extreme position.

3. The position in which it will finally *rest* is determined by the *maximum* value of $\Sigma u_1 + \Sigma u_2$ in equation 1; for, by a well-known property, the *vis viva* of a system* attains a maximum value when it passes through a position of stable, and a minimum, when it passes through a position of unstable equilibrium. The extreme position into which the body oscillates is therefore essentially different from that in which it will finally rest.

4. Different bodies, requiring different amounts of work to be done upon them to bring them to the same given inclination, *that* is (relatively to that inclination) the most stable, which requires the greatest amount of work to be so done upon it, or in respect to which Σu_1 is the greatest. If, instead of all being brought to the same given inclination, each is brought into a position of unstable equilibrium, the corresponding value of Σu_1 represents the amount of work which must be done upon it to *overthrow* it, and may be considered to measure its *absolute*, as the former value

* POISSON, Mécanique, Art. 571.

7. Let a body be conceived to float, acted upon by no other forces than its weight W , and the upward pressure of the water (equal to its weight); which forces may be conceived to be applied respectively to the centre of gravity of the body and to the centre of gravity of the displaced fluid; and let it be supposed to be subjected to the action of a third force whose direction is parallel to the surface of the fluid. Let ΔH_1 represent the vertical displacement of the centre of gravity of the body thereby produced*, and ΔH_2 that of the centre of gravity of its immersed part. Let moreover the volume of the immersed part be conceived to remain unaltered† whilst the body is in the act of displacement. If each centre of gravity be assumed to ascend, the work of the weight of the body will be represented by $-W.\Delta H_1$, and that of the upward pressure of the fluid by $+W.\Delta H_2$, the negative sign being taken in the former case, because the force acts in a direction opposite to that in which the point of application is moved, and the positive sign in the latter, because it acts in the same direction, so that the aggregate work Σu_2 (see equation 1.) of the forces which constituted the equilibrium of the body in the state from which it has been disturbed is represented by

$$-W.\Delta H_1 + W.\Delta H_2.$$

If the centre of gravity of the body or of the displaced fluid *descends* (a property which will be found to characterize a large class of vessels), ΔH_1 in the one case, and ΔH_2 in the other, must be taken with the negative sign, since the weight of the body will be applied in the same direction, and the pressure of the fluid in an opposite direction to that in which their respective points of application are moved. Moreover, the system put in motion includes, with the floating body, the particles of the fluid displaced by it as it changes its position, so that if the weight of any element of the floating body be represented by w_1 , and of the fluid by w_2 , and if their velocities be v_1 and v_2 , the whole *vis viva* is represented by

$$\frac{1}{g}\Sigma w_1 v_1^2 + \frac{1}{g}\Sigma w_2 v_2^2,$$

and we have by equation 1,

$$U(\theta) - W(\Delta H_1 - \Delta H_2) = \frac{1}{2g}\Sigma w_1 v_1^2 + \frac{1}{2g}\Sigma w_2 v_2^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.)$$

In the extreme position into which the body is made to roll and in which $\Sigma w_1 v_1^2 = 0$,

$$U(\theta) = W.(\Delta H_1 - \Delta H_2) + \frac{1}{2g}\Sigma w_2 v_2^2, \quad . \quad . \quad . \quad . \quad . \quad . \quad (5.)$$

* When a floating body is so made to incline from any one position into any other as that the volume of fluid displaced by it may in the one position be equal to that in the other, its centre of gravity is also vertically displaced; for if this be not the case, the perpendicular distance of the centre of gravity of the body from its plane of flotation must remain unchanged, and the form of that portion of its surface, which is subject to immersion, must be *determined geometrically* by this condition; but by the supposition the form of the body is undetermined. It is remarkable what currency has been given to the error, that whilst a vessel is rolling or pitching its centre of gravity remains at rest. I should not otherwise have thought this note necessary.

† It will be shown that this supposition is only approximately true.

or if the inertia of the displaced fluid be neglected,

$$U(\theta) = W.(\Delta H_1 - \Delta H_2). \quad (6.)$$

Whence it follows that the work necessary to incline a floating body through any given angle is equal to that necessary to raise it bodily through a height equal to the difference of the vertical displacements of its centre of gravity and of that of its immersed part, so that other things being the same, that ship is the most stable the product of whose weight by this difference is the greatest.

In the case in which the centre of gravity of the displaced fluid descends, the *sum* of the displacements is to be taken instead of the difference.

8. This conclusion is nevertheless in error in the following respects:—

1st. It supposes that throughout the motion the weight of the displaced fluid remains equal to that of the floating body, which equality cannot accurately have been preserved by reason of the inertia of the body and of the displaced fluid*.

From this cause there cannot but result small vertical oscillations of the body about those positions which, whilst it is in the act of inclining, correspond to this equality, which oscillations are independent of its principal oscillation.

2ndly. It involves the hypothesis of absolute rigidity in the floating body, so that the motion of every part and its *vis viva* may cease at *once* when the principal oscillation terminates. The frame of a ship and its masts are however elastic, and by reason of this elasticity there cannot but result oscillations, which are independent of, and may not synchronize with, the principal oscillation of the ship as she rolls, so that the *vis viva* of every part cannot be assumed to cease and determine at one and the same instant, as it has been supposed to do.

3rdly. No account has been taken of the work expended in communicating *motion* to the displaced fluid, measured by half its *vis viva* and represented by the term $\frac{1}{2g} \sum w_i v_i^2$ in equation 5.

9. From a careful consideration of these causes of error, I was led to conclude that they would not affect that practical application of the formula which I had principally in view in investigating it, especially as in certain respects they tended to neutralize one another. The question appeared however of sufficient importance to be subjected to the test of experiment, and on my application, the Lords Commissioners of the Admiralty were pleased to direct that such experiments should be made in Her Majesty's Dockyard at Portsmouth, and Mr. FINCHAM, the eminent

* The motion of the centre of gravity of the body being the same as though all the disturbing forces were applied directly to it, it follows, that no elevation of this point is caused in the beginning of the motion, by the application of a horizontal disturbing force, or by a horizontal displacement of the weight of the body, which, if it be a ship, may be effected by moving its ballast. The motion of rotation thereby produced takes place therefore, in the first instance, about the centre of gravity, but it cannot so take place without destroying the equality of the weight of the displaced fluid to that of the body. From this inequality there results a vertical motion of the centre of gravity, and another axis of rotation.

Master Shipwright of that dockyard, and Mr. RAWSON were kind enough to undertake them.

The details of these experiments accompany my paper ; they extend beyond the object originally contemplated by me ; and whether regard be had to the practical importance of the question under discussion, the great care and labour bestowed upon them, or the many expedients by which these gentlemen have succeeded in giving to them a degree of accuracy hitherto, I believe, unknown in experiments of this kind, they claim to rank as authentic and valuable contributions to the science of naval construction.

10. That it might be determined experimentally whether the work which must be done upon a floating body to incline it through a given angle be that represented by equation 6, it was necessary to do upon such a body an amount of work which could be measured ; and it was further necessary to ascertain what were the elevations of the centres of gravity of the body and of its immersed part thus produced, and then to see whether the amount of work done upon the body equaled the difference of these elevations multiplied by its weight.

To effect this, I proposed that a vessel should be constructed of a simple geometrical form, such that the place of the centre of gravity of its immersed part might readily be determined in every position into which it might be inclined, that of its plane of flotation being supposed to be known ; and that a mast should be fixed to it, and a long yard to this mast, and that when the body floated in a vertical position a weight suspended from one extremity of the yard should suddenly be allowed to act upon it causing it to roll over ; that the position into which it thus rolled should be ascertained, together with the corresponding elevations of its centre of gravity and the centre of gravity of its immersed part, and the vertical descent of the weight suspended from the extremity of its arm. The product of this vertical descent by the weight suspended from the arm ought then, by the formula, to be found nearly equal to the difference of the elevations of the two centres of gravity multiplied by the weight of the body ; and this was the test to which I proposed that the formula should be subjected, having in view its adoption by practical men as a principle of naval construction.

To give to the deflecting weight that *instantaneous* action on the extremity of the arm which was necessary to the accuracy of the experiment, a string was in the first place to be affixed to it and attached to a point vertically above, in the ceiling. When the deflecting weight was first applied this string would sustain its pressure, but this might be thrown at once upon the extremity of the arm by cutting it. A transverse section of the vessel, with its mast and arm, was to be plotted on a large scale on a board, and the extreme position into which the vessel rolled being by some means observed, the water-line corresponding to this position was to be drawn. The position of the yard, in respect to the surface of the water in that position, would then be known, and the vertical descent of the deflecting weight could be measured, and also the vertical ascent of the centre of gravity of the immersed part or displacement.

Fig 1.

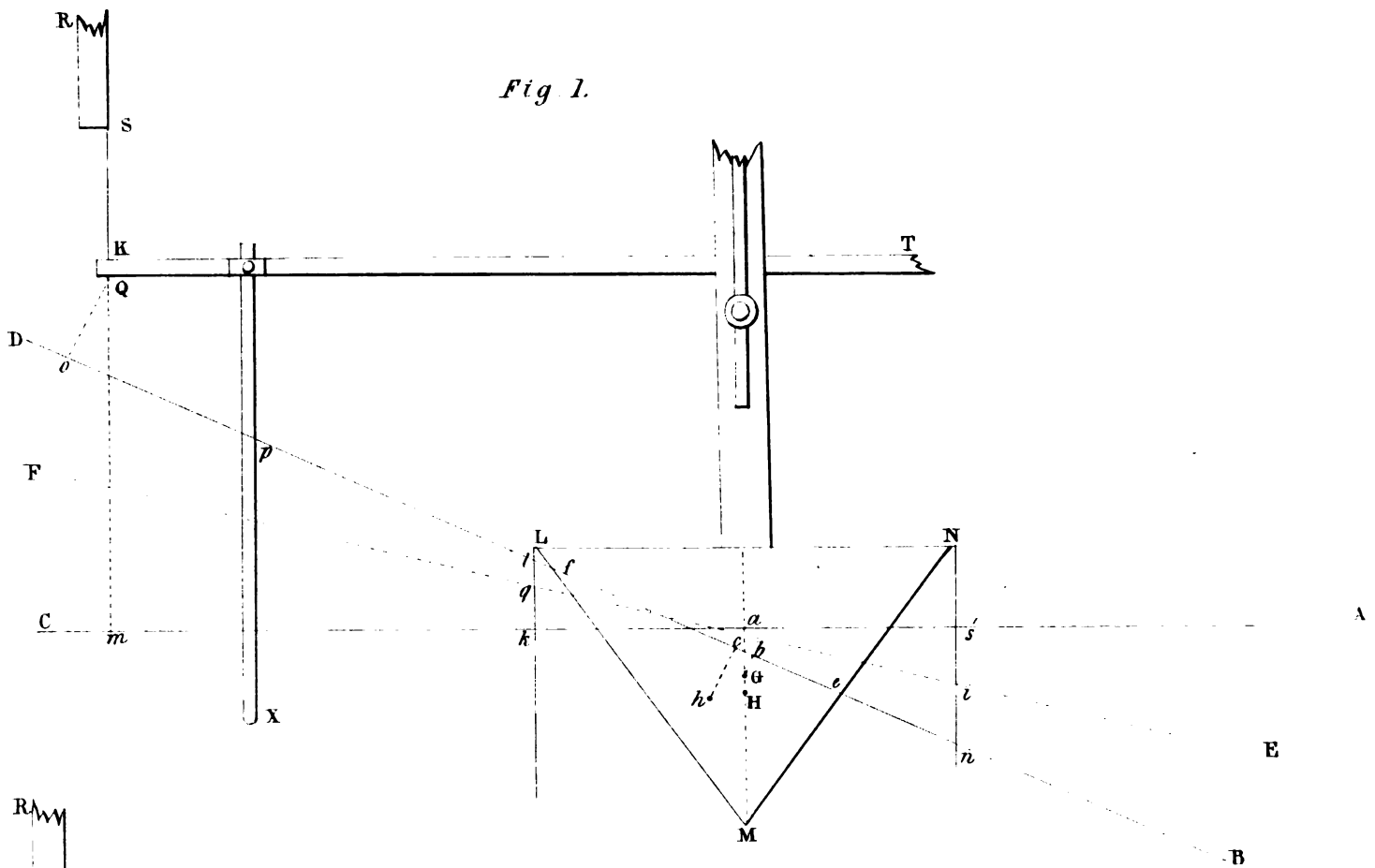
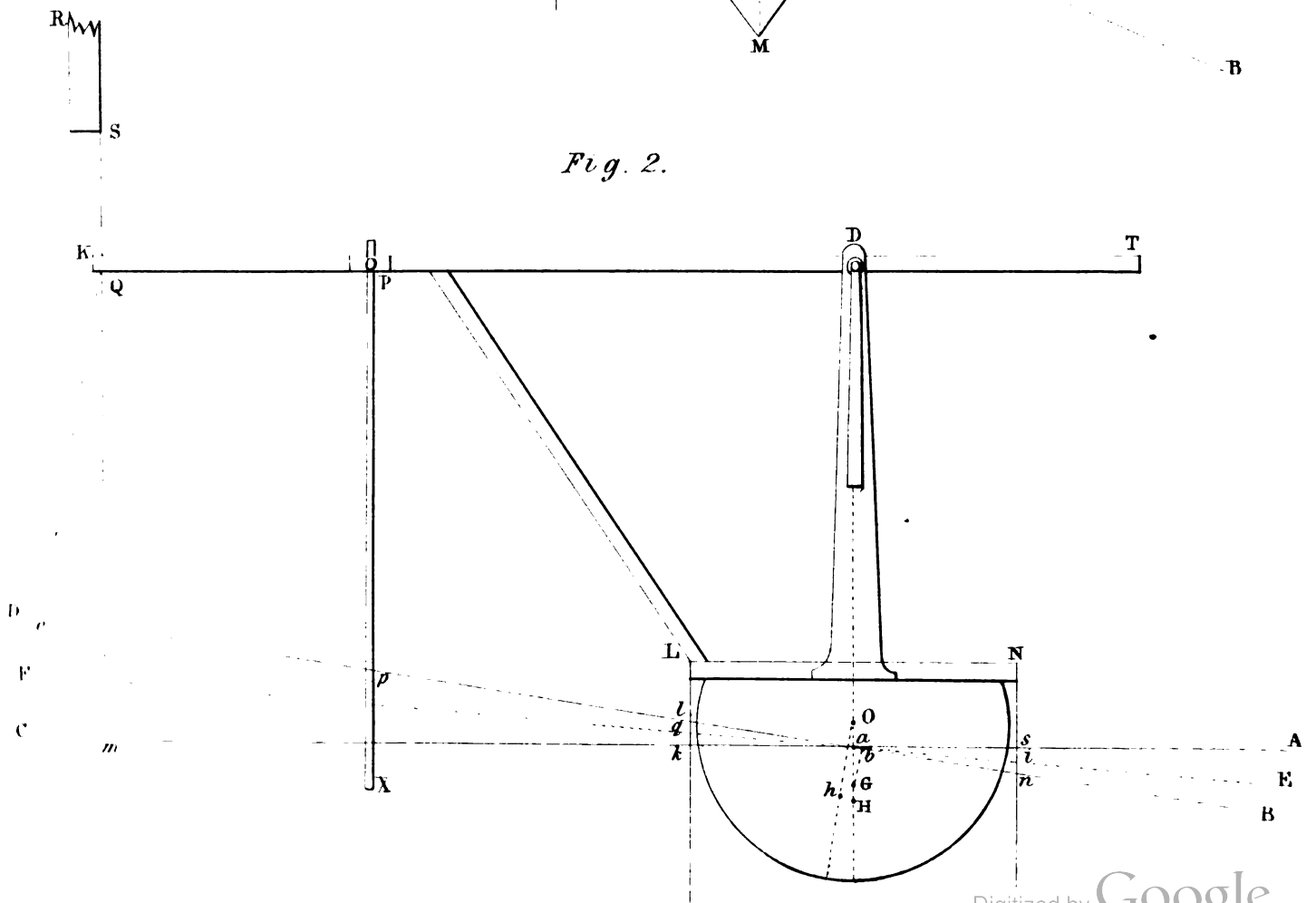


Fig. 2.



To determine the position of the centre of gravity of the vessel, it was to be allowed to rest in an inclined position under the action of the deflecting weight; and the water-line corresponding to this position being drawn on the board, the corresponding position of the deflecting weight and of the centre of gravity of the immersion were thence to be determined. The determination of the position of the vertical passing through the centre of gravity of the body would thus become an elementary question of statics; and the intersection of this line, with that about which the section was symmetrical, would mark the position of the centre of gravity. This determination might be verified by a second similar experiment with a different deflecting weight.

These suggestions have received a great development at the hands of Mr. RAWSON, and he has adopted many new and ingenious expedients in carrying them out. Among these, that by which the position of the water-line was determined in the extreme position into which the vessel rolls, appears to me specially worthy of observation. A strip of wood was fastened at right angles to that extremity of the yard to which the deflecting weight was attached, of sufficient length to dip into the water when the vessel rolled, on this slip of wood, and also on the side of the vessel nearest to it, a strip of glazed paper was fixed. The highest points at which these strips of paper were wetted in the rolling of the vessel, were obviously points in the water-line in its extreme position, and being plotted upon the board, a line drawn through them determined that position with a degree of accuracy which left nothing to be desired.

11. Two forms of vessels were used (see Plate XLVII. figs. 1 and 2); one of them had a triangular and the other a semicircular section. The following Table contains the general results of the experiments, of which the particulars are detailed in the Appendix:—

Form of the model experimented on.	No. of experiment.	Weight of model and loading.	Disturbing weight.	Dynamical stability, as determined by experiment.	Dynamical stability calculated from the formula $U(\theta) = W\Delta(H_1 - H_2)$.	Extreme inclination into which the vessel rolled, as determined by experiment.	Extreme inclination into which the vessel should roll, as determined by calculation from the formula $U(\theta) = W\Delta(H_1 - H_2)$ *.	Inclination in which the vessel finally rested when subjected to the action of the disturbing weight.	Ratio of the volume of the displaced fluid in the extreme position into which the vessel rolled to that in the position in which it originally rested.
Triangular model.	1.	33·8626	·5485	·5161	·5361	23° 30'	°	12° 30'	·8961
	2.	36·8590	·3450	·4887	·4951	15 30	.....	8 0	·98114
	3.	37·3563	·5377	1·1724	1·4503	24 0	.....	13 0	·88512
	4.	38·2911	·5739	1·2673	1·8460	25 0	.....	13 30	·9330
Circular model.	1.	197·18	2·8225	7·3761	7·394	26 0	24 20	13 0	
	2.	197·18	1·9570	3·2486	3·122	17 0	16 22	9 0	
	3.	255·43	1·9570	1·7727	1·7667	10 0	10 0	4 30	

In the experiments with the smaller triangular model the differences between the

* The inclinations are calculated by the formula (9.).

results and those given by the formula are much greater than in the experiments with the heavier cylindrical vessel.

In explanation of this difference, it will be observed, *first*, that the conditions of the experiment with the cylindrical model more nearly approach to those which are assumed in the formula than those with the other; the disturbance of the water in the change of the position of the former being less, and therefore the work expended upon the inertia of the water, of which the formula takes no account, less in the one case than the other; and, *secondly*, that the weight of the model being greater, this inertia bears a less proportion to the amount of work required for inclining it than in the other case.

The effect of this inertia adding itself to the buoyancy of the fluid, cannot but be to lift the vessel out of the water and to cause the displacement to be less at the termination of each rolling oscillation than at its commencement*. This variation in volume of the displacement was apparent in all the experiments. Its amount was measured and is recorded in the last column of the Table; its tendency is to produce in the body vertical oscillations, which are so far independent of its rolling motion that they will not probably synchronize with it. The body displacing, when rolling, less fluid than it would at rest, the effect of the weight used in the experiments to incline it is thereby increased, and thus is explained the fact (apparent in the eighth and ninth columns of the Table) that the inclination by experiment is somewhat greater than the formula would make it.

12. *The dynamical stability of a vessel whose athwart sections (where they are subject to immersion and emersion) are circular, having their centres in a common axis.*

Let EDF, Plate XLVIII. fig. 3 or 4, be an athwart section of such a vessel, the parts of whose periphery ES and FR, subject to immersion and emersion, are parts of the same circular arc ETF, whose centre is C. Let G_1 represent the projection of the centre of gravity of the vessel on this section, and G_2 that of the centre of gravity of the space whose section is SDRT, supposing it filled with water. This space lies wholly within the vessel in fig. 3 and without it in fig. 4. Let

$$h_1 = CG_1, \quad h_2 = CG_2.$$

W_1 = weight of vessel.

W_2 = weight of water occupying, or which would occupy, the space whose section is STRD.

θ = the inclination from the vertical.

Since in the act of the inclination of the vessel the whole volume of the displaced fluid remains constant, and also that volume of which STRD is the section†, it follows that the volume of that portion of which the circular area PSRQ is the section

* This result connects itself with the well-known fact of the rise of a vessel out of the water when propelled rapidly, which is so great in the case of fast track-boats, as considerably to reduce the resistance upon them.

† It will be observed that the space STRD is supposed always to be under water.

remains also constant, and that the water-line PQ, which is the chord of that area, remains at the same distance from C, so that the point C neither ascends nor descends. Now the forces which constituted the equilibrium of the vessel in its vertical position were its weight and that of the fluid it displaced. Since the point C is not vertically displaced, the work of the former force, as the body inclines through the angle θ , is represented by $-W_1 h_1$ vers θ . The work of the latter is equal to that of the upward pressure of the water which would occupy the space of which the circular area PTQ is the section *increased*, in the case represented in fig. 3, by that of the water which would occupy STRD; and *diminished* by it in the case represented in fig. 4.

But since the space, of which the circular area PTQ is the section, remains similar and equal to itself, its centre of gravity remains always at the same distance from the centre C, and therefore neither ascends nor descends. Whence it follows that the work of the water which would occupy this space is *zero*; so that the work of the *whole* displaced fluid is equal to that of the *part* of it which occupies the space STRD, taken in the case represented in fig. 3 with the positive, and in that represented in fig. 4 with the negative sign. It is represented therefore generally by the formula $\pm W_2 h_2$ vers θ . On the whole, therefore, the work Σu_2 (see Art. 1.) of those forces, which in the vertical position of the body constituted its equilibrium, is represented by the formula

$$\Sigma u_2 = -W_1 h_1 \text{ vers } \theta \pm W_2 h_2 \text{ vers } \theta.$$

Representing therefore the dynamical stability Σu_1 by $U(\theta)$, we have by equation (2.)

$$U(\theta) = (W_1 h_1 \mp W_2 h_2) \text{ vers } \theta, \quad (7.)$$

in which expression the sign $\mp$ is to be taken according as the circular area ATB lies wholly within the area ADB, as in fig. 3, or partly without it, as in fig. 4. Other things being the same, the latter is therefore a more stable form than the former.

13. The work of the upward pressure of the water upon the vessel represented in fig. 4 being a negative quantity, $-W_2 h_2$ vers θ , it follows that the point of application of the pressure must be moved in a direction opposite to that in which the pressure acts; but the pressure acts upwards, therefore its point of application, *i. e.* the centre of gravity of the displaced fluid, *descends*. This property may be considered to distinguish *mechanically* the class of vessels whose type is fig. 3, from that class whose type is fig. 4; as the property of including wholly or only partly, within the area of any of their athwart sections, the corresponding circular area ETF, distinguishes them geometrically.

14. To obtain from the formula 7 an expression adapted to the experiments with the circular model, Plate XLVII. fig. 2, let

$$OM = b, \quad MQ = c, \quad \text{Disturbing weight} = w.$$

Now it may readily be shown that the vertical descent of the point Q, when the vessel is made to incline through the angle θ , is represented by

$$b \text{ vers } \theta + c \sin \theta.$$

ζ = inclination to horizon of line about which the plane PQ is symmetrical.

x = distance of section CAD, measured along the line whose projection is O, from the point where that line intersects the midship section.

$y = O\beta$.

$y_1 = PQ$.

$y_2 = RS$.

$z = hn + mg$.

$\lambda = KL$.

I = moment of inertia of plane PQ about axis O.

A and B = moments of inertia of PQ about its principal axes.

μ = weight of a cubic unit of water.

Suppose the water actually *displaced* by the vessel to be, on the contrary, *contained* by it; and conceive that which occupies the space QOS to pass into the space POR, the whole becoming solid. Let ΔH_1 represent the corresponding elevation of the centre of gravity of the whole contained fluid. Then will $\Delta H_1 + \Delta H_2$ represent the total elevation of the centre of gravity of this fluid as it passes from the position it occupied when the vessel was vertical into the position PAQ. But this elevation is obviously the same as though the fluid had assumed the solid state in the vertical position of the body, and the latter had revolved with it, in that state, into its present position. It is therefore represented by $KH - NH^*$;

$$\therefore \Delta H_1 + \Delta H_2 = KH - NH \text{ and } \Delta H_2 = KH - NH - \Delta H_1.$$

Since, moreover, by the elevation of the fluid in QOS, whose weight is w , into the space OPR, and of its centre of gravity through $(gm + hn)$, the centre of gravity of mass of fluid of which it forms a part, and whose weight is W , is raised through the space ΔH_2 ; it follows, by a well-known property of the centre of gravity of a system†, that

$$W \cdot \Delta H_2 = w(gm + hn);$$

$$\therefore W(KH - NH - \Delta H_2) = w(gm + hn).$$

But

$$NH = KH \cos \theta - KL = H_2 \cos \theta - \lambda;$$

$$\therefore KH - NH = H_2 \text{ vers } \theta + \lambda,$$

and

$$mg + nh = z;$$

$$\therefore W(H_2 \text{ vers } \theta + \lambda - \Delta H_2) = wz;$$

$$\therefore W \cdot \Delta H_2 = W(H_2 \text{ vers } \theta + \lambda) - wz. \quad \dots \dots \dots (10.)$$

* The line joining the centres of gravity of the vessel and its immersed part, in its vertical position, is parallel to the plane CAD, for it is perpendicular to the plane PQ, to whose intersection with the plane RS the plane CAD is perpendicular; $\therefore GK = H_1$ and $HK = H_2$.

† PONCELET, *Mécanique Industrielle*, 2^{me} partie, Art. 50, or MOSLEY'S *Mechanical Principles of Engineering*, Art. 59.

Also $\Delta H_1 = KG - MG = H_1 - (H_1 \cos \theta - \lambda) = H_1 \text{ vers } \theta + \lambda;$
 $\therefore W(\Delta H_1 \mp \Delta H_2) = W(H_1 \mp H_2) \text{ vers } \theta + wz^*;$
 $\therefore (\text{equation 6.}) U(\theta, \eta) = W(H_1 \mp H_2) \text{ vers } \theta + wz; \quad (11.)$

the sign $\mp$ being taken according as the vessel is of the class represented in fig. 3, in which the centre of gravity of the displaced fluid ascends, or of that represented in fig. 4, in which it descends.

If $\alpha\beta$ be a vertical prismatic element of the space QOS, whose base is $dx dy \cos \theta$, and height $y \sin \theta$, then will $w \cdot \overline{mg}$ be represented, in respect to that element, by $\mu y \sin \theta \cdot dx dy \cos \theta \cdot \frac{1}{2} y \sin \theta$, or by $\frac{1}{2} \mu \sin^2 \theta \cos \theta y^2 dx dy$; and wz will be represented, in respect to the whole space of which $PrsQ$ is the section, by

$$\frac{1}{2} \mu \sin^2 \theta \cos \theta \iint y^2 dx dy,$$

or by $\frac{1}{2} \mu \sin^2 \theta \cos \theta \cdot I.$

If therefore we represent by ϕ the value of wz , in respect to the spaces of which the mixtilinear areas PrR and QsS are the sections, we have

$$wz = \frac{1}{2} \mu I \sin^2 \theta \cos \theta + \phi.$$

But the axis O , about which the moment of inertia of the plane PQ is I , is inclined to the principal axes of that plane at the angles η and $\frac{\pi}{2} - \eta$, about which principal axes the moments of inertia are A and B ; and it has been shown by M. DUPIN† that when θ is small the line in which the planes PQ or RS intersect passes through the centre of gravity of each;

$$\therefore I = A \cos^2 \eta + B \sin^2 \eta;$$

therefore by equation (11.),

$$U(\theta, \eta) = W(H_1 \mp H_2) \text{ vers } \theta + \frac{1}{2} \mu (A \cos^2 \eta + B \sin^2 \eta) \sin^2 \theta \cos \theta + \phi. \quad . . . (12.)$$

If θ be so small that the spaces PrR and QsS are evanescent in comparison with POr and QOs , then, assuming $\phi = 0$ and $\cos \theta = 1$,

$$U(\theta, \eta) = W(H_1 \mp H_2) \text{ vers } \theta + \frac{1}{2} \mu (A \cos^2 \eta + B \sin^2 \eta) \sin^2 \theta, \quad (13.)$$

which may be put under the form

$$U(\theta, \eta) = \left\{ W(H_1 \mp H_2) + \mu (A \cos^2 \eta + B \sin^2 \eta) \right\} \text{ vers } \theta.$$

Again, since

$$\sin \zeta = \sin \theta \sin \eta, \quad (14.)$$

* The sign $\mp$ is here taken to include the case in which the centre of gravity of the displaced fluid descends.
 See Art. 7.

† Sur la Stabilité des Corps Flottants, p. 32.