Philosophy for Heroes
Part III: Act

PHILOSOPHY FOR HEROES

PART III: ACT

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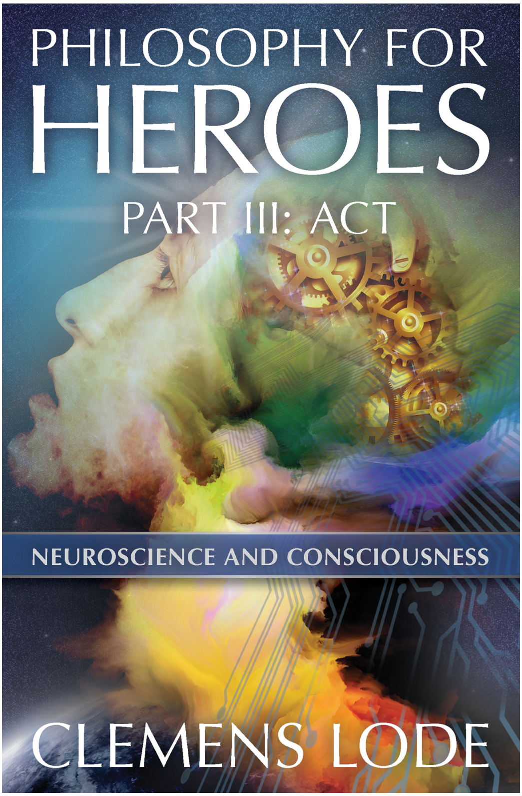

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NEUROSCIENCE
PHILOSOPHY
POPULAR SCIENCE
PSYCHOLOGY

Dedication

I drew my motivation to write this book from something the neuroscientist Michael Graziano said:

> You go to a conference on consciousness, and in some ways, I feel like I'm at a conference on Tolkien's Middle Earth. And everyone is talking about Middle Earth. Are Orcs really Elves that got modified and this and that and you can talk and talk about it and what it is really magic in Middle Earth and then I'm the iconoclast who is foolish enough to say yeah, that's true, but that's all a description of something and it exists only in simulation. It exists only as information, only as a description. There actually isn't a real Middle Earth. Well, you could say it's a description of a real thing because it's a kind of warped description of Medieval Europe, but it doesn't exist physically as such, and this is very much what I would say about awareness. —*Michael Graziano, Closer to Truth*, 2015

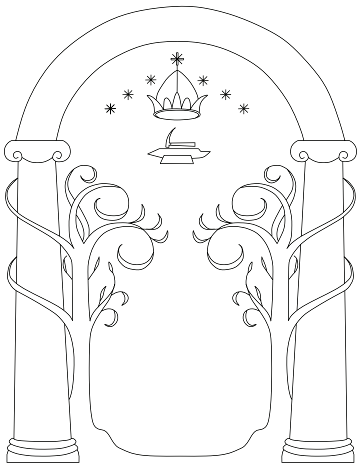

Figure 1: "The Doors of Durin, Lord of Moria. Speak 'friend' and Enter!" —*Lord of the Rings*

Introduction

In this book, I will examine, from the ground up, questions about consciousness. Many steps toward the understanding of the self will tell you nothing about the self—until your right hemisphere connects everything into one idea as you understand the concept. Such an insight is also called an *epiphany*. Using a brain scanner, we can actually observe someone having an epiphany when the brain's right hemisphere suddenly buzzes with activity. While the left hemisphere deals with concrete entities, the right hemisphere helps with looking for alternative meanings. For example, the left hemisphere might identify a "bank" as a financial institution, while the right hemisphere also considers it to be the edge of a river ("river bank").

In the Old Indo-Aryan language Sanskrit, an *epiphany* leading you to the answer about who you are is called "bodhi," which literally means "awakening" or "enlightenment." Similarly, the name "Buddha" means the "Awakened One" or the "Enlightened One." A similar idea can be found in Zen Buddhism as *Satori* (Japanese 悟り) which corresponds to a very *sudden* insight.

This book shows some of the steps leading to Satori, combining the insights of philosophers and scientists into a new idea of what the "self" means. With this knowledge, we can better reflect on our own values and *act* according to reality rather than just blindly following someone else's beliefs. The book series *Philosophy for Heroes* offers the intellectual and moral know-how necessary to be a leader who neither has followers, nor follows other leaders.

Contents

Publisher's Note

Writing and editing this third book of the series turned out to be a major challenge. Not only did it lead me to change my views on free will and consciousness, but I also discovered it will take more time to put my thoughts into words. That is the reason I split the topics of free will and consciousness into two books. This book will focus on the brain and how it creates consciousness, and the next book will focus on free will and ethics. Consequently, there will be a fifth book focusing on leadership, religion, and heroism.

That being said, the actual process of creating this book has been very rewarding. With the help of the book template (as discussed in *Better Books with LaTeX the Agile Way*), I was able to speed up the writing process and am very pleased about the result. What helped me also was reaching into the community by starting a small local Meetup group and receiving a lot of feedback.

Thank you for keeping up the tradition of reading books. You and your fellow readers have created a market for this book. I hope that I can meet your expectations and I am looking forward to feedback, no matter whether it is positive or negative. To send general feedback, mention the book title in the subject of your message and simply send it to feedback@lode.de. You can also contact us at https://www.lode.de/contact if you are having a problem with any aspect of the book, and we will do our best to address it. Also, we cordially invite you to join our network at https://www.lode.de.

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Preface

> “We are not always what we seem, and hardly ever what we dream.
>
> —Peter S. Beagle, *The Last Unicorn*

Imagine one of our ancestors in the distant past, sitting near a lake, lost in thought. She looks into the water and sees her reflection. Then, for the first time in the evolutionary history of humans, the question is asked, “What is this experience I have of myself?” Unbeknownst to her, that question would vex humanity through modern times. Today, there is again an entity looking into a proverbial lake and examining its reflection: while artificial intelligence is still in its infancy, it is on the verge of recognizing itself and asking the same question, “Who am I?”

The closer we come to a machine that seems to be as intelligent as a human being, the more we start to worry about our own subjective experience. If a computer eventually becomes indistinguishable from us, what makes humans special? What is our role in the universe if we are so similar to a computer program? *Does your brain need a self at all?*

My goal with the *Philosophy for Heroes* series is to give you a comprehensive overview from the very fundamental ideas of ontology (“What is?”) and epistemology (“How do we know?”) through the fields of psychology, ethics, and leadership. By being able to reflect on who we are, we can become better leaders.

Sitting on my balcony and watching the stars in the clear sky, I am grateful for the past 10 years I spent in research and emotional development. I see how people are struggling to cope with the current crisis, be it with anxiety, hate, or outright denial. Reality is tough as it can be unforgiving, without a political agenda, and final. In a way, studying science is a coping mechanism, too. If I know how scary things work, they lose part of their power. If I understand how A will lead to B, I do not have to hide under the bed because B might jump through the door at any moment. I can look for evidence for A or try to evade or prepare for it.

What I wrote five years ago in *Philosophy for Heroes: Knowledge* remains true:

> “I hope that you will take with you from this book series one or two exciting ideas, and develop them further or let them inspire you. Personally, I would like to place this book in the hands of a younger version of myself, someone who finds him- or herself at the beginning of his or her journey of scientific discovery, having to first wade through tons of misinformation before getting to the “good stuff.” Even if I reach only a small handful of people who will take to heart a few of these core ideas and set out to achieve something great in life themselves—whatever that might be—I will be able to enjoy the rewards of this book. I made the book available to the public just as I would plant a handful of seeds in the earth, hoping that they grow and bloom.

In *Philosophy for Heroes: Knowledge*, we started our journey into philosophy with the intuitive understanding that the world consists of entities which we can objectively perceive. For this, we need to keep going back and forth between information we gather about the world (*ontology*) and about how we perceive the world (*epistemology*). Whenever we discover something new, we should re-examine how this affects our knowledge and perception of the world. For example, if we find out that someone is a liar, we should re-examine what we learned from that person.

In *Philosophy for Heroes: Continuum*, we formalized this approach with the scientific method. Using this tool, we explored ontological questions in physics and biology to answer questions about the origin of the universe and life.

In *Philosophy for Heroes: Act*, we will continue with the scientific approach to explore the evolutionary history and architecture of the brain. Using these new insights, we will draw conclusions on how we experience the world and create a sense of self-consciousness.

You, the reader, are holding the open book in your hands and now have an overview of what to expect.

Let us continue our journey to become a shining example for others, thus getting closer to our ideal world. The path to our goal is the *Philosophy for Heroes.*

Clemens Lode
Düsseldorf, Germany, November 1st, 2020

You can find chapters 1 and 2 in

PHILOSOPHY FOR HEROES

PART I: KNOWLEDGE

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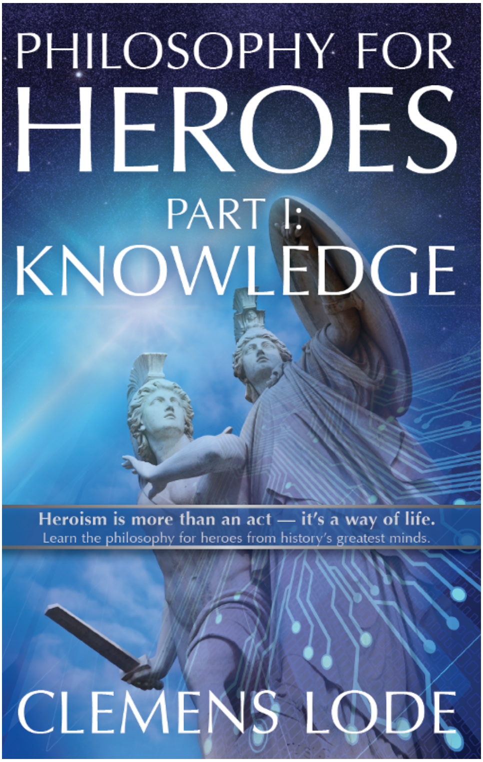

You can find chapters 3 and 4 in

PHILOSOPHY FOR HEROES

PART II: CONTINUUM

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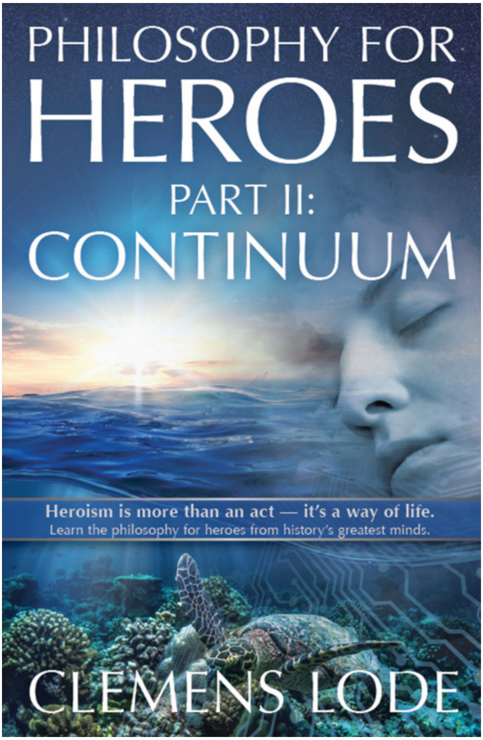

Chapter 5

The Brain

> “ Our imagination is stretched to the utmost, not, as in fiction, to imagine things which are not really there, but just to comprehend those things which are there.
>
> —Richard P. Feynman, *Character of Physical Law*

When we look at a picture or a scene, we take for granted that what we are seeing is the entire picture, that we have an objective view, and that what we see is real. However, we are not cameras. We *think* we have looked at the whole picture or scene, but, in reality, we likely have perceived only a filtered version of it, and all we might remember are several details that caught our attention. To explore this curious difference between our experience and reality, the first step is to understand the brain's architecture. Given that consciousness must sit somewhere between perception and action, we will examine the entire stream of data, from sense data to action.

The Evolution of Attention. Before we can discuss the brain's higher functions, we first have to understand all its parts. The best approach is to look at its evolution from the first multi-cellular lifeforms and work our way up to the brain of modern mammals.
The Rise of the Primates. To comprehend the most modern part of our brain, the neocortex, we have to go into depth and compare our brain to that of our closest cousins, the apes. Then, to gain insight into how our brain evolved, we also need to take a look at the environments in which our human ancestors spent most of their evolutionary history.
A Glimpse into the Brain. To learn about our subjective experience of the world, we need to look at how sense data arrive in and are processed by our brain. For this, we examine the visual system from the eyes to the visual cortex.
Creating a Body Schema. To understand how our brain initiates actions, we need to know how the brain gains a sense of our body. We build a body schema to be able to differentiate between ourselves and our environment.
Theory of Mind. Finally, we need to explain how the brain makes sense of itself. Consciousness goes beyond seeing oneself in the mirror; it also involves knowing what we (and other people) are thinking about.

5.1 The Evolution of Attention

What evolutionary steps contributed to the development of the conscious experience and process of decision-making humans possess today?

Figure 5.1: What we most closely connect to someone's attention are his eyes. Not only can the eyes tell us what someone is looking at, but they can also give us hints about what someone might be thinking (image source: Shutterstock).

> **ATTENTION** · *Attention* is the brain's process of limiting alternative thought patterns, then increasing the most dominant thought pattern's strength. It is like a simple majority rule: the most successful thought pattern gets all the resources while other thought patterns are suppressed. While we can jump back and forth between different thoughts, we cannot have two dominant thought patterns at the same time.

Attention refers to the ability to select between competing or even contradicting sense data. For example, you hear something on your left, see something moving on your right, you are hungry, and tired; which sense data gets your attention first? The brain parts involved that help us make such a decision underwent half a billion years of evolution and can be traced back to simple multi-cellular organisms.[1] Figure 5.2 shows the evolutionary timeline of primates with different species branching off. As we are looking only at the evolution of attention, our focus will be a small selection of species rather than a comprehensive discussion. Figure 5.3 shows the same tree of dependencies in a graphical form, with branches representing the creation of new major species.

Time	**Species**	**Brain part**
600 mya	sponges	calcium signalling
580 mya	*Hydras*	basic nerve net
550 mya	arthropods	information classification
535 mya	lancelets	olfactory system
520 mya	fish	optic tectum (information tracking)
520 mya	fish	thalamus (information integration)
520 mya	fish	basal ganglia (resolving conflicts)
520 mya	fish	amygdala (information evaluation)
520 mya	fish	hippocampus (spatiotemporal memory)
450 mya	sharks	cerebellum (movement programs)
300 mya	reptilians	wulst (high-level processing)
225 mya	mammals	neocortex (similar to wulst)
55 mya	primates	prefrontal cortex (planning)

Figure 5.2: Timeline (in million years ago) of the evolution of attention in animals with a list of species that branched off the evolutionary tree and the brain part that first appeared at that time.

[1] Kaas, 2017, p. 547–554.

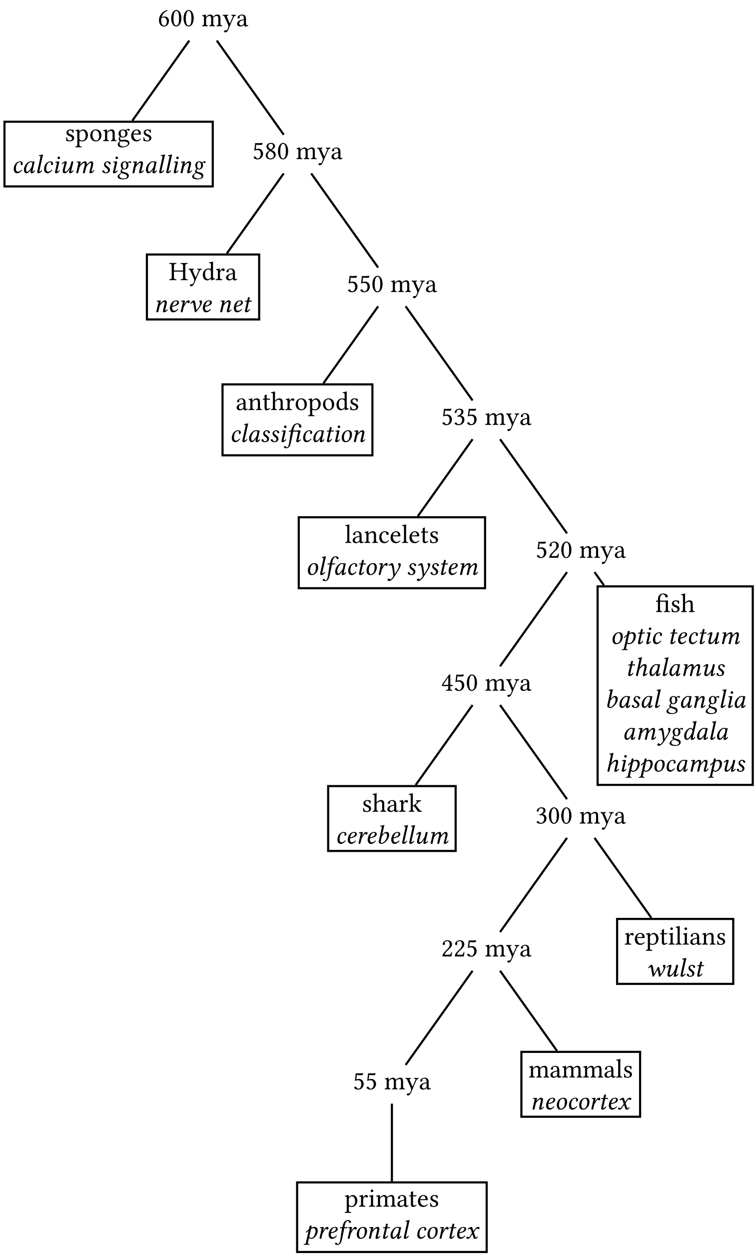

Figure 5.3: Simplified evolution of attention in animals.

Over this long history, the brain became a collection of different functions, layered on top of each other, with many systems having overlapping responsibilities. If a neural pathway helped one of your ancestors to avoid danger, that pathway survived, even if that meant that the architecture became somewhat chaotic ("complex").

Nature does not care about an easy-to-understand architecture; it cares only about what works and what does not.

Sometimes, the organization of a certain function into clearly distinct brain parts had an evolutionary advantage (for example, separating the *neocortex* from the rest of the brain). In other cases, the most efficient layout was having one function directly beside the other (for example, the different brain regions within the necortex). Yet, for our understanding of the brain, it is sufficient to look at it as a system of separate parts interacting with each other. We just have to keep in mind that the functions of brain parts usually blend into those of neighboring brain parts, and that there are many more interactions and connections between brain parts than listed here.

Major structural components and properties of the brain include:

> **Allocortex** · The *allocortex* is part of the cerebral cortex (the *neocortex* is the other part) and consists of the olfactory system and the hippocampus.

> **Neocortex** · The *neocortex* is the newest part of the mammalian brain and consists of the *cerebral hemispheres.* Its main tasks are focus, language, long-term planning, and modelling of the world. It can generate strategies that involve detours if goal-directed behavior is not successful (for example, going around a fence instead of trying to get through it).

> **Cerebrum** · The *cerebrum* includes the neocortex (the cerebral hemispheres), and the allocortex (the hippocampus, the basal ganglia, and the olfactory bulb).

Cerebral cortex · The *cerebral cortex* is the outer layer of the cerebrum. It contains most of the neurons of the brain.

Gyrus · A *gyrus* is a fold or ridge in the cerebral cortex.

Sulcus · A *sulcus* is a groove in the cerebral cortex.

5.1.1 Nerve Nets in Hydras

Looking at our tree of animal ancestors (see Figure 5.3) in regard to brain development, sponges were the first to settle into an evolutionary niche (more than 600 million years ago). They are sea animals that are mostly immobile and simply filter oxygen and nutrients from the ocean water. Although they have a primitive way of pushing water, when it is toxic or otherwise polluted, out of their bodies, they lack any form of nervous system as we understand it. Their cells communicate directly with each other using calcium signalling. Each cell contains a concentration of calcium that can be released if it receives calcium from neighboring cells. This way, it creates a calcium wave propagating throughout the organism. You can imagine it like having many square containers grouped together and filled to the brink with water. When you take one container and pour it into its neighboring containers, all the containers will overflow.

The first animals with some semblance of a brain were *Hydras*. They branched off our evolutionary tree more than 580 million years ago. They are small (around 10 millimeters in length) animals that usually attach themselves to the surface of an object in their environment and can slowly move over it or detach themselves and float in the water. They have a basic nervous system that allows them to use their tentacles to attack prey. If another animal (mostly tiny planktonic crustaceans like *Daphnia* or *Cyclops* up to five millimeters in length) touches a tentacle, the nerve cells activate the tentacle to take that animal into the *Hydra*'s mouth. There is no central nervous system that organizes this activation. Instead, nerve cells are spread throughout the body of the *Hydra* in a nerve net. This enables the *Hydra* to respond to its environment without being able to detect where this original stimulus came from. Any signal leads to the same reaction—for example, all muscles contract at the same time.

If the human body had a nerve net instead of a nervous system and brain, we would not be able to figure out where we were touched, only that we felt *something* and as a result had to come up with a general response to this touch. Such a general response is comparable to our hormonal system: for example, the adrenaline released in a situation of danger does not cause specific actions but prepares the whole body for a possible injury or energy exertion. Another example would be the regulation of body temperature which, again, is a general response to certain conditions instead of a specific movement.

5.1.2 Classification of Signals in Arthropods

A basic form of attention appeared at the time the arthropods (insects, spiders, crabs, etc.) split off the evolutionary tree around 550 million years ago. With this new form of attention, instead of treating all sensory input as equal, the information is pre-processed and can thus be amplified and classified. Imagine noticing something suddenly moving in the grass—it immediately draws your attention. Once you see it emerging from the grass, you classify it as a particular concept, for example, a snake.

At its core, classification is about *filtering* information we do not need. No longer would every signal cause a reaction. Instead, the organism was able to focus on specific signals and react to those.

Dog at 1pm	**Dog at 2pm**	**Analysis**
Basket	Basket	Dog has not moved
Rug	Rug	Dog has not moved
Basket	Rug	Dog has moved
Rug	Basket	Dog has moved

Figure 5.4: Example for an application of the XOR filter. If the dog is at different places at 1pm and 2pm, we can conclude that the dog has moved.

Most multi-layered nervous systems (including our own) support this kind of filtering. By comparing several images on your retina for changes, your visual system can make out which moving part belongs to which previously seen part. For example, if your visual system identifies a dog and then the same dog in subsequent images, you perceive any changes in those images as movements of the dog. If you closed your eyes every second, you would perceive the dog "jumping" from place to place. You would have to use your short-term memory as a workaround and remember where the dog was earlier to decide whether or not he had moved. Figure 5.4 shows an example that represents the function *XOR* ("eXclusive OR") which filters out similarities and returns differences. When passing two images through such an XOR filter, it would highlight changes between both images and thus detect movement.

Visual pre-processing is done partly by the retina of our eyes, detecting edges and changes, and compressing the data-stream toward the rest of the visual system. To understand what is happening, imagine looking at a picture of a palm tree in front of a white background. The brain perceives the detailed raw image, then the visual system extracts the edges of objects to identify them (see Figure 5.5). This way, the brain can determine that there is the shape of a palm tree. This is the opposite of what happens when *drawing* a picture: we *start out* with the palm tree in mind, then draw the edges and contours and then finally fill them in with details.

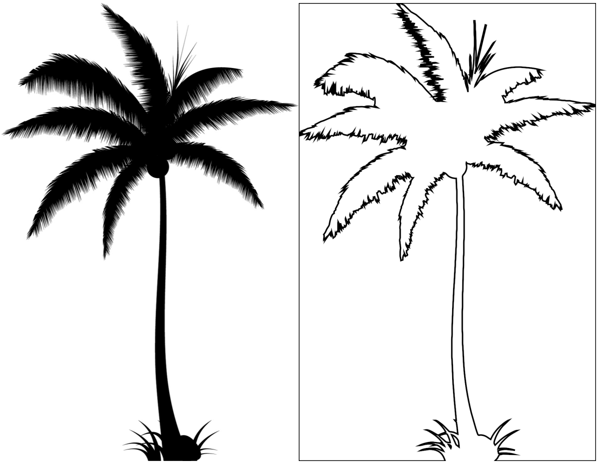

Figure 5.5: Edge detection applied to the image of a palm tree (image source: Shutterstock).

Beyond being just a one-way street of information (classifying the image data to abstract information), classification systems can also help you to direct attention. When we see things that are new or unusual, our brain allocates resources to finding out what they are. This could play out by turning our head, refocusing our eyes, looking at things from a different perspective, going closer, or asking others about the new or unusual things.

5.1.3 The Olfactory System in Lancelets

The olfactory system was probably one of the earliest sense organs that evolved in animals, as detecting molecules is closely connected to a lifeform's search for nutrients. While not directly related to us (they diverged from our ancestors around 535 million years ago), we share some of our olfactory-related genes with lancelets (see Figure 5.6). They can be seen as predecessors of fish with similar organs

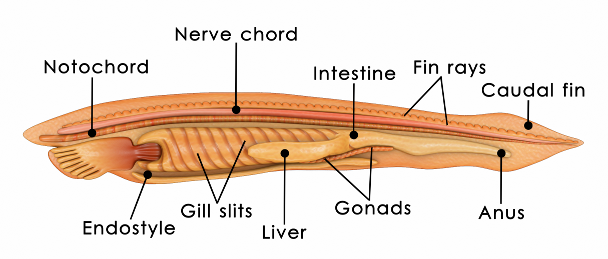

Figure 5.6: Lancelets can be seen as predecessors of fish with similar but more primitive organs (image source: Shutterstock).

but in more primitive form. For example, their gill-slits are used for feeding but not for respiration. Likewise, their circulatory system transports nutrients but not oxygen. While they have no centralized olfactory system (we humans do), their olfactory receptors are studded along their flanks to detect possible sources of nutrition in their aquatic environment.

Molecules connect to the olfactory system over the peripheral olfactory system. In aquatic animals, this happens directly via contact with the water. In land animals with lungs, this happens by having the airborne molecules dissolve into mucus on top of the olfactory receptor cells. If the molecule binds to the receptor cell, a nerve signal is created and transmitted to the brain. A peculiarity of our sense of smell is that it is the only sense that can bypass the thalamus (see Chapter 5.1.5) and send signals directly to the neocortex.

While our sense of smell might seem to play little to no role in our modern hectic life, it actually has a significant impact. In combination with our sweat, our sense of smell can communicate emotions. Usually, we think of emotions being contagious by way of our sense of sight or sense of hearing—we tend to laugh when we see or hear someone else laugh. But studies have shown that emotions are also contagious via our sense of smell. This works even when the smell is separate from the person (for example, on his clothes). So, even without words or gestures, people can communicate their distress to others nearby.[2] The evolutionary advantage of this mechanism makes sense, especially when it comes to fear. Putting yourself into a heightened state of alertness when detecting fear in other people can increase your chances of survival.

The olfactory system also supports mate selection by detecting pheromones which contain the MHC complex. In *Philosophy for Heroes: Continuum*, we discussed the relevancy of the MHC complex in the immune system's ability to differentiate self from other. In mate selection, a similar system is used to find a partner that is genetically not too similar but also not too different. The evolutionary advantage is to have a compatible partner with increased resistance to infectious diseases by providing a variability in the MHC complex.[3] At the same time, it reduces the chance for children to inherit genetic diseases. Similar to the immune system, the olfactory system probably becomes accustomed to the MHC complex of relatives in early childhood. If this contact does not happen, there is no biochemical obstacle to falling in love with close relatives.[4]

In terms of brain architecture, information travels not only from the olfactory system to the brain, but also in the opposite direction. If a particular faint smell wins the neural competition, resources are allocated to enhance our olfactory system's sensitivity. This focus can improve the olfactory system's efficiency by providing context information. In fact, the information from the millions of odor detectors in the olfactory system never even arrives at our neocortex. Instead, it is condensed into only 25 cells which are primed by the neocortex. If there is a strong smell, the sensitivity of the cells is reduced; if we want to pick up a faint smell, we can increase the sensitivity.

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[2] Mujica-Parodi et al., 2009.
[3] Ejsmond, Radwan, and Wilson, 2014.
[4] Potts and Wakeland, 1993.

By combining the gustatory system (the basic tastes sensed by the tongue like salty, sour, bitter, umami, sweet, kokumi, calcium, and so on) with the smells detected by our nose, we can enhance our overall experience of food. Children learn to like or dislike certain types of food when observing what is safe for other people to eat.[5] While individual exceptions exist, if humans were genetically disposed to favor a particular food (like Koala bears prefer eucalyptus tree leaves) to the exclusion of other foods, our ancestors would have had a hard time spreading all over the globe.

If the olfactory system classifies something as inedible, it might initiate the gag reflex to protect the body from poisons. If we actually get food poisoning or an infection, the body reacts by increasing acetate levels in the blood. In the brain, this improves the ability to create memories. The evolutionary advantage of this pathway could be to better remember the situation that led to the food poisoning or infection and thus prevent it in the future.

All these properties are reflected in the architecture of the olfactory system. There are the following connections (Figure 5.7):

- Trigeminal nerve, vagus nerve (gagging reflex, face muscles, expression of disgust);
- Hippocampus (spatial memory);
- Amgydala, hypothalamus (emotional reaction, hormones, pheromone processing);
- Neocortex (processing of smells);
- Hippothalamus (pheromones, hormones);
- Olfactory bulb (sensory cells); and
- Nose (air flow).

[5] Elsaesser and Paysan, 2007.

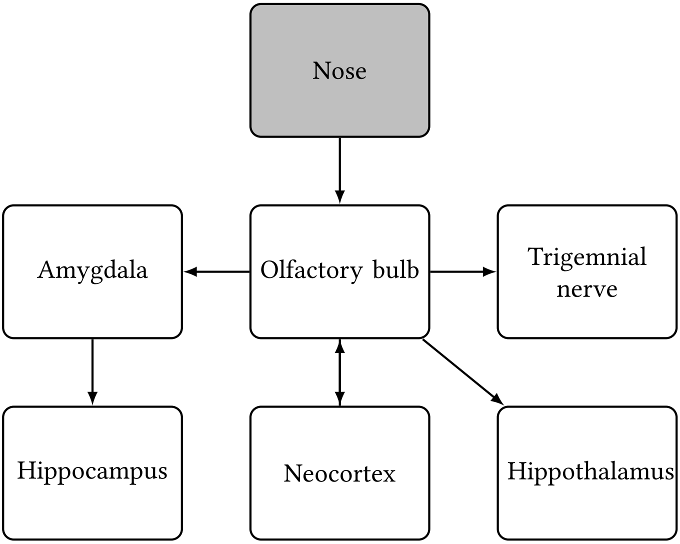

Figure 5.7: The architecture of the olfactory system.

5.1.4 The Optic Tectum in Fish

Controlling eye movements made it necessary for fish (they split from the evolutionary tree around 520 million years ago) to develop central processing, namely the *optic tectum*. In mammals, this organ is called the *superior colliculus* and most of the processing has moved to the visual cortex. It helps fish (and us) to track moving objects and is responsible for blinking as well as pupillary and head-turning reflexes. Relying on auditory information, the superior colliculus is also responsible for reflexively turning one's eyes and head toward a sound source.

In the brain, the superior colliculus sits right behind the optic chiasm where the nerves from the left eye and right eye cross. If something or someone outside of your eyes' focus moves, this part of the brain is responsible for bringing it to your attention. You might then turn your head and re-focus your eyes to get a better picture of the possible threat. Imagine you did not have this reflex to see anything moving in your environment. The risk of injury (say, from an oncoming tiger) would be much higher because of your longer reaction time.

> **Superior colliculus** · The *superior colliculus* or *optic tectum* (in non-mammals) helps the eyes to track objects, and controls blinking, pupillary, and head-turning reflexes.

5.1.5 The Thalamus in Fish

On the evolutionary timeline, the *thalamus* also first appears in fish. It combines and pre-processes different sources of sensory information into a coherent whole before relaying it to other parts of the brain:

- It combines the information from the left eye and right eye to build a three-dimensional representation of the environment.
- In humans, it translates the signals from the red, green, and blue cone cells in the retinas into colors. While further processing takes place in the neocortex, the first part responsible for this color encoding is the *lateral geniculate nucleus* (or LGN).
- Like the superior colliculus, the LGN also receives auditory information. The LGN changes the auditory information so that you perceive the sound as coming from a visual source. For example, when watching television, the LGN "moves" the perceived location of the source of sound from the speakers to the screen.[6]

[6] McAlonan, Cavanaugh, and Wurtz, 2006.

Thalamus · The *thalamus* integrates different sensory information and relays the information to other brain parts. For example, it combines sense data from the retinas' cones into colors, or calculates three-dimensional information from the two-dimensional images from both eyes.

Lateral geniculate nucleus · The *lateral geniculate nucleus* (LGN) is part of the thalamus and relays information from the retinas (via the optic chiasm) to the visual cortex. It pre-processes some of the information, for example, combining red, green, and blue photoreceptor cells into colors.

5.1.6 The Basal Ganglia in Fish

For the evolutionary competition of neurons (that we have discussed in *Philosophy for Heroes: Continuum*) to work, research points to an involvement of the basal ganglia.[7] The *basal ganglia* are thought to originate from the need to arbitrate between different courses of motor neuron activation. They identify the "best" among several possibly contradicting courses of action. Rules determine what "best" means in a particular context. For example, you can have the two competing thoughts (e.g., wanting to go left and to go right), but you cannot physically walk in two directions at once.

Basal ganglia · The *basal ganglia* are a part of the brain that, like a referee, arbitrate decisions by the neural committees. Also, like an orchestra conductor, they coordinate the sequence of entire motor programs. In both cases, they do not make decisions but merely provide rules and structure.

Beyond selecting individual motor actions, the basal ganglia seem to be involved in cognitive thought patterns. While contradicting thoughts can exist, different thought patterns cannot recruit the

[7] Redgrave, Prescott, and Gurney, 1999.

same cognitive resources at the same time. For example, imagining a unicorn leads to thought patterns recruiting parts of your visual cortex. Adding more elements to the scene requires more and more resources until you can no longer focus on all elements at the same time. The basal ganglia are also involved in coordinating entire motor programs. Imagine an orchestra without a conductor: sure, the musicians could play their respective parts, but at different speeds and starting at different points in time. The basal ganglia act like a conductor of an orchestra, synchronizing the different motor programs, activating them in the right sequence and with the right timing.

5.1.7 The Amygdala in Fish

Yet another brain part, the *amygdala*, first appeared in fish. Managing our attention with the basal ganglia is one thing, how we *prioritize* the signal is another. While we can make decisions based on the strength of the signal—turning our head to the loudest noise seems to be a good strategy—we also need to put the signal into context. For example, instead of always running away from a tiger, we might consider whether or not to take the risk and first pick some berries and only then run away—especially if we are very hungry. This demonstrates how the amygdala uses information from a number of sources to prioritize different courses of action.

> **AMYGDALA** · The *amygdala* is the brain's value and emotion center. It helps with evaluating thought patterns of the basal ganglia depending on the context instead of the mere strength of the signal. It also connects the brain with the hippothalamus, providing a bridge to the hormonal system.

With its connection to the hormonal system, the amygdala also initiates fight, flight, freeze, or fawn responses when in distress:

- Attack the predator ("fight" response);
- Run away from the predator ("flight" response);
- Remain still ("freeze" response); or
- Display submissive behavior ("fawn" response, by humans and other social animals).

How the fight and flight responses can help in a threatening situation is self-explanatory. The "freeze" response can trick predators because many predators' instincts depend on motion. If their prey is not moving, the predator's hunting instinct is not activated and they will look elsewhere for food. For example, cats take great interest in a moving toy while they might ignore something that remains still. Similarly, the "fawn" response works if the attacker is from the same species and also a social animal. Showing submissive behavior communicates to the other party that you are not a threat, preventing possible injury for both parties.

Beyond helping with the immediate response (e.g., releasing adrenaline), it can also serve as an early basic form of memory. For the response to be effective, the hormonal changes caused by, for example, the flight response need to remain long after a predator has vanished from an animal's view. It will cause it either to head home to a safe place or to be on alert when it returns to this location.

The information the amygdala is using is limited to immediately available sensory data. It activates emotional reactions based on mapping the input from the thalamus to emotional behavior. For example, the sight of fresh berries might evoke a positive emotional response while the sound of a rival might evoke a fight, flight, or fawn response. This response takes priority over any rational evaluation of the situation because it is quicker and possibly stronger than signals coming from the neocortex. The amygdala associates sense data coming through the thalamus with positive or negative events and, ultimately, emotions, for example:[8] Tiger ⇒ fear; apple ⇒ appetite; and sun ⇒ happiness. What makes this mechanism so powerful is that it requires very little processing power while it can cover a wide range of sensations. The major limitation of behavior based on the amygdala is the limited range of reactions and the reliance on immediately available sense data. The amygdala cannot take into account abstract thinking or planning, or complex relationships between objects, animals, or people.

5.1.8 The Hippocampus in Fish

A predecessor of our *hippocampus* also developed around the time of the first fishes. The actual hippocampus is unique to mammals but there are theories that similar structures evolved from a common ancestor of reptiles and mammals around 520 million years ago. Its main task is to create a mental map of an animal's environment to allow the animal to remember where possible food and water sources are located. It also helps with navigation, remembering paths the animal has taken, relating spatially to other animals or objects,[9] and recognizing places for orientation. A good example for the use of the hippocampus is squirrels burying nuts as food stashes for the winter. Our current understanding is that this map is not a literal map but instead consists of points of orientation. While many people can construct a mental image of a map, we tend to orient ourselves by seeing something we know and then putting our goal in relation to the landmark. For example, when describing to another person the path to a location, we might say "Walk down the street until you get to the large tower, then turn right."

[8] Tye et al., 2008; Rogan, Stäubli, and LeDoux, 1997; McKernan and Shinnick-Gallagher, 1997.

[9] Danjo, Toyoizumi, and Fujisawa, 2018.

Hippocampus · The brain's *hippocampus* provides us with a mental map for navigation. It also builds temporal relationships between places, allowing us to determine, for example, which areas in our environment we have already foraged and in which areas the plants have regrown. The *hippocampus* and the *olfactory system* (sense of smell) make up the *allocortex*.

While earlier animals could drift and react to sensory inputs (evading predators and approaching food), once the food was out of sight, it was also out of mind. The hippocampus allowed animals to find more food by avoiding areas that they had already foraged and exploring areas they had not foraged. This requires mapping the environment based on odors (the sense of smell has direct connections to the hippocampus) and sights, as well as prioritizing those according to the time they should be visited.[10] This led to the evolution of the hippocampus to handle tasks in serial order with the right timing and in the right context. This stems from its ability to associate two memories with each other, which helps to find a path from one place to another.[11]

Did you know?

The hippocampus' function becomes most visible during dreams, when experiences retained during the day are played back for long-term memory backup in the neocortex. While we cannot ask animals whether or not they dream, some animals show rapid eye movements (REM) in their sleep, pointing to an activation of their hippocampus.

⟶ Read more in *Philosophy for Heroes: Persona*

[10] Murray, Wise, and Graham, 2018.
[11] Samsonovich and Ascoli, 2005.

5.1.9 The Cerebellum in Sharks

More than 450 million years ago, sharks with a *cerebellum* emerged. This organ coordinates complex, time-critical behavior which includes movements, speech, and balance. When hunting, the shark might have had to outmaneuver its prey and then bite at the right moment. Similarly, its prey had to come up with movement strategies to navigate through the water to evade predators, locking predator and prey into an evolutionary race. Mammals face similar challenges of coordination when trying to jump from tree to tree, evade attacks by predators, or catch prey. Given that both the cerebellum and the basal ganglia are involved in coordinating motor programs, it is no surprise that they also form an integrated network to exchange information.[12]

> **CEREBELLUM** · The *cerebellum* is the brain part that helps with coordination of complex behavior. It provides a set of motor programs the brain can choose from repeatedly for similar actions (even in time-critical situations). With the help of the cerebellum we can, for example, walk or bicycle without having to consciously think of each movement.

In more general terms, the cerebellum is responsible for replaying movements. This becomes apparent when examining how the cerebellum learns new movements. Think about how each leg moves, as you did when you first learned to walk or to ride a bicycle: the programs to coordinate all your motor neurons were not yet transferred to your cerebellum ("learned"). Thus, they were not yet optimized and consequently, they were very slow. Until that optimization happened, walking or riding a bike had not become "second nature." You had to take "baby steps" and focus on one step or motion at a time before making the next one.

[12] Bostan and Strick, 2018.

In the (very rare) case of people born without a cerebellum, we see late walking development, reduced gait speed, unsteady gait, and a reduced ability to stand in darkness or when their eyes are closed.[13] This is explained by the fact that the cerebellum is connected to the inner ear, providing our sense of balance. In addition, people born without a cerebellum have late speech development, slurred and slowed speech, and a reduced control of pitch and loudness. This points to an additional role of the cerebellum in language fluency.[14]

5.1.10 The Neocortex in Mammals

The neocortex, which is layered over the *collicular control* of attention (above the previously mentioned superior colliculus), developed more than 300 million years ago. Following the Permian-Triassic mass extinction event 252 million years ago (extinguishing 70% of land biodiversity), both the dinosaurs and mammals emerged. Given that dinosaurs still dominated the planet, mammals had to move into a niche and become nocturnal animals. According to the *nocturnal bottleneck hypothesis*, traits of growing fur, managing body temperature, and well-developed senses of smell, hearing, and touch helped our ancestors to stay active at night while evading predators during the day.

> **Nocturnal bottleneck hypothesis** · The *nocturnal bottleneck hypothesis* posits that many mammalian traits were adaptions to moving into a niche to become nocturnal animals and evade the dominant dinosaurs.

Functions of the neocortex include sensory perception, conceptualization, directed motor commands, spatial reasoning, communication, and long-term planning. The visual field is analyzed to create a mental representation of objects and their location. Instead of the

[13] Yu et al., 2014.
[14] Carta et al., 2019.

raw sense data, this mental representation of the world is then used by the rest of the brain in, for example, coordination with motor control, language (reading this book), or face recognition. Similarly, other senses (hearing, touch, smell, etc.) are processed, and their signals are categorized and prioritized.

While we are now aware of the principal brain functions we share with other mammals, the question remains what makes us humans unique. In Chapter 5.2, we will look at how our human ancestors adapted to the Savannah and how that set them apart from their closest primate cousins, the chimpanzees, that stayed behind in the forest.

5.2 The Rise of the Primates

To understand human nature, we can compare ourselves with our closest primate cousins, the chimpanzees. How do we differ, what makes us special, and what has taken us on two different paths?

Some 66 million years ago, a 10km- to 15km-wide asteroid hit what we today know as the Gulf of Mexico and in its aftermath killed all animals over 55 pounds body weight (the *Cretaceous-Paleogene extinction event*). This opened an opportunity for the smaller mammals to slowly return from their nocturnal life. Prior to this fateful event, mammals had adapted by hiding during the day. At night, they relied on their sense of smell to evade predators and to locate prey. This led them to evolve abilities that turned out to be useful when they returned to the daylight. One of those abilities was suppressing immediate urges. With the help of the *prefrontal cortex*, the mammal was able to save valuable time and energy. It could ignore scents of predators that were long gone, and pursue prey that was still nearby.

> **Prefrontal cortex** · The *prefrontal cortex* is part of the frontal lobe and can be understood as running a simulation of the world. It monitors social relationships, keeps track of objects when they are no longer visible (object permanence), and helps with the pursuit of long-term goals. It has only indirect connections to brain parts dealing with actions or sense perception.

When mammals later adapted to the daylight, the same principle was applied to visual data. For example, just seeing a lion does not mean that the lion is dangerous; it might be sleeping. To make that judgement call, the separate evaluation and signal by the prefrontal cortex was needed as a counterbalance, thinking long-term, balancing risk and reward.

The prefrontal cortex is only indirectly connected to any sensory organs or muscles, hence it is believed to process thoughts that do not need any external input to be activated and do not necessarily result in a concrete action to be executed. Put differently, the prefrontal cortex reads and controls the rest of the brain instead of directly accessing sense organs or muscles.

To understand the prefrontal cortex' role, we need to remember that many parts of the brain are in competition with each other. In that regard, the prefrontal cortex can be understood as a counterbalance to the rest of the brain. Applications include long-term goals, social rules, hidden threats, imagination, or memories. For example, a strong visual input like a tiger standing in front of us would need an equally strong competing signal to prevent a simple fight, flight, fawn, or freeze reaction.

5.2.1 The Primary Motor Cortex

The first true primate ancestor was a small nocturnal monkey-like, forest-dwelling animal (*Plesiadapis*) that lived in trees and ate fruit (around 55 million years ago). This primate-like mammal needed strength and balance to jump from tree to tree, and a brain that could calculate movement in three-dimensional space, as opposed to just navigating on the ground. Also, its eyesight had to improve to adapt to the light of day and to recognize ripe fruit. A testament to this evolutionary history is that we now lack the ability to produce our own vitamin C and need to rely on a steady diet of fruit and vegetables.

About 30 million years ago, the evolutionary branch split into Old World monkeys and New World monkeys. The most widely held theory about this split is that the ancestors of the New World monkeys used a temporary land bridge or series of islands between Afro-Eurasia and South America. The main difference between the two types of monkeys is that New World monkeys kept their tail. With their *primary motor cortex* (see Chapter **??**) being focused on their tail muscles, they use it like a fifth limb. In contrast, the primary motor cortex of apes (Old World monkeys) is specialized for hand use which helps with foraging for fruit. To observe this in humans, just stand in a modern supermarket and watch people carefully checking out the ripeness of avocados.

> **PRIMARY MOTOR CORTEX** · The *primary motor cortex* is part of the frontal lobe and is directly adjacent to the primary somatosensory cortex of the parietal cortex. This way, it can directly process data from our sense of touch to better control movements. The *primary motor cortex* connects to the *brainstem* and *spinal cord* (via the *upper motor neurons*) which in turn connect to the muscles (via the lower motor neurons).

The feature that makes the primary motor cortex in primates special compared to that of other mammals is that it can bypass the spine's interneurons (the spine's relay station) and send signals directly to the motoneurons of the spine.[15] With a significantly higher number of neurons controlling the movement, this allows fine-grained control of the actual signals sent to the muscles. This part of the brain also grew overproportionally during the evolution of primates.[16]

Why exactly do more neurons lead to better control?

Our primary motor cortex contains about 5 billion neurons controlling some 600 muscles. Those 600 muscles consist of more than 50 billion muscle cells. But muscles can only contract, so, theoretically, to contract all 600 muscles individually, no more than 600 motor neurons would be needed. Signals arriving in the primary motor cortex already contain the specific motor program, so all that is left for the primary motor cortex to do is to translate those into signals associated to individual muscles.

Let us imagine two extreme architectures:

1. **If any nerve detects a signal, all muscle cells contract.** This is the case with the nerve net in the previously discussed *Hydra* (see Chapter 5.1.1). As fewer motor neurons need to be activated, this option is extremely energy-efficient and quick: each movement could be done with maximum strength in the blink of an eye. Theoretically, you would need only a single nerve cell to control all muscles in your body. On the other hand, the only possible action you could take is to contract all muscles at the same time. Imagine you could fully exert your biceps with the same mental effort it takes to move your little finger. You would leave the gym with sore muscles but

[15] Rathelot and Strick, 2009.
[16] Rowe, Macrini, and Luo, 2011.

mentally, you would still feel refreshed. The downside is that you would not have any precision if all you could do is exert full force or exert no force at all.

2. **Each muscle cell is connected to an individual nerve cell coordinating whether or not it contracts.** A movement can involve any number of muscle cells in any combination and sequence, allowing very fine-grained control of the position of the limbs as well as the force exerted with each movement. This option is very energy intense, though. Not only would your body have to provide energy for your muscles to work, your nerve cells would take a similar amount of energy to operate the muscles. Our brain uses around 10 billion neuron cells to control 50 billion muscle cells. To reach a level of control where one neuron cell controls one muscle cell, our brain would have to be around 50% larger than its current size (our brain has around 86 billion neurons and would need around 126 billion neurons).

Our own primary motor cortex resembles the latter architecture more than the former. Compared to our more powerful cousins, the chimpanzees, our primary motor cortex is about 20% to 70% larger.[17] In chimpanzees, the relatively small number of motor neurons can be activated very quickly, allowing for greater strength. On the other hand, the higher number of motor neurons in humans allows for more precise movements and significantly less energy expenditure by the muscles. This gives us better control over how much force we want to exert—a crucial ability when it comes to using (or producing) more advanced tools like bows or spears.[18]

[17] Donahue et al., 2018.
[18] Walker, 2009.

5.2.2 The Rise of the Hominids

Further splits occurred about 15 million years ago (gibbons), 13 million years ago (orangutans), and 10 million years ago (gorillas), with the final split from chimpanzees and humans between four million and 13 million years ago. From there, we can trace back our human ancestors, with their most distinctive feature being a progressively increasing brain volume:

- *Australopithecus* (3.6 million years ago, 485 cm^3)
- *Homo habilis* (2.1 million to 1.5 million years ago, 650 cm^3)
- *Homo erectus* (2 million to 0.14 million years ago, 1100 cm^3)
- *Homo heidelbergensis* (0.7 million to 0.2 million years ago, 1230 cm^3)
- *Homo neanderthalensis* (250 thousand to 40 thousand years ago, 1500–1740 cm^3)
- *Homo sapiens* (today, 1425 cm^3)

With Neanderthals having had larger brains than humans, were they more intelligent than humans?

To answer this question, it is important to note that besides humans and their ancestors, other animals also have large brains. For example, bottlenose dolphins have a similar brain size as humans have. They have been observed helping out other dolphins as well as those of other species like humans (e.g., drowning divers), which points to them sharing our ability to understand what other beings are possibly thinking or experiencing.[19] But to compare brain sizes between humans and other animals, we need to include their *body size* into our calculation. Larger bodies produce a larger quantity of signals

[19] cf. White, 2007, p. 41.

that need to be processed and have more muscle cells that need to be activated. For example, while whales have a brain size more than five times that of humans, they are not necessarily quick (or creative) thinkers. They need that brain size to control the muscles in and the sensors of their huge body (around 50 tons). Thus, to get a sense about an animal's intelligence, we need to look at the total brain size divided by the body mass, and set it in relation to the average (for the species) brain size and body mass. This so-called *encephalization quotient* (EQ) provides such a mapping, making it possible to compare different animals' potential intelligence (see Figure 5.8).[20]

> **ENCEPHALIZATION QUOTIENT** · The *encephalization quotient* (EQ) is a measure of relative brain size and is often used to convey how small or large a species' brain is compared to that of other species of similar body size.

Species	**EQ**	**Cranial capacity**
Human	7.4–7.8	1250–1450 cm^3
Neanderthal	7	1600 cm^3
Bottlenose dolphin	5.3	1350 cm^3
Homo erectus	5	1100 cm^3
Homo habilis	4.3	650 cm^3
Eurasian magpies	2.49	5 cm^3
Australopithecus	2.5	485 cm^3
Chimpanzee	2.2–2.5	330–430 cm^3
Gorilla	1.5–1.8	500 cm^3
Whale	1.8	2600–9000 cm^3
African elephant	1.3	4200 cm^3
Dog	1.2	64 cm^3
Cat	1.0	25 cm^3

Figure 5.8: Comparison of different species' brain size sorted by their relative encephalization quotient.

[20] Roth and Dicke, 2005.

As the table shows, when accounting for their larger body mass, the encephalization quotient of Neanderthals is similar to that of modern humans. And it has been shown that Neanderthals created and used tools like spears, possibly had language, and developed their own cultures. *So, how do we differ from Neanderthals?*

We find a clue by looking at gorillas. With an encephalization quotient of 1.5, they are at the lower end of the EQ spectrum—while clearly highly intelligent given that they can learn sign language and make and use simple tools. This points to the EQ not telling the entire story. Hence, scientists have divided the brain mass further into parts necessary for the maintenance and control of the body and senses, and those associated with improved cognitive capacities.[21] Subsequent studies on Neanderthal brains[22] have shown that they must have had significantly larger eyes (possibly to allow better sight for hunting where there was not much light) than those of humans. Also, the brain part responsible for image processing must have been larger, which left less brain mass for social relationship processing. The currently accepted theory is that humans used their social intelligence as an advantage over Neanderthals, ultimately replacing them—even though the latter possessed better sight and body control. Research seems to point to multiple migrations from Africa to Europe[23] and back from Europe to Africa[24] with interbreeding over a prolonged timespan.

Further research needs to be done in regard to arthropods (insects, spiders, etc.) and cephalopods (especially cuttlefish, squid, and octopodes). For example, jumping spiders are able to plan ahead and to apply hunting strategies, and even care for and nurse their young like mammals do.[25] This is reflected in their brain-to-body ratio: a jumping spider's brain requires so much space that it is distributed

[21] Roth and Dicke, 2012.
[22] Pearce, Stringer, and Dunbar, 2013.
[23] Kuhlwilm et al., 2016.
[24] L. Chen et al., 2020.
[25] Z. Chen et al., 2018.

throughout its tiny body. Another example would be octopodes; they have two-thirds of their nervous systems in their arms, resulting in a brain-to-body quotient comparable to that of humans. Octopodes can use tools, solve puzzles, recognize people, and plan ahead.

In the case of some animals, to counter the size limitations of the brain, the brain uses *cortical folding* to increase surface area and processing speed.[26] Imagine that very early during embryonic development, the neurons form a flat plane and then fold while the surface area is growing. This is comparable to creating towels by adding loops of thread (the folds) to a piece of cloth. They increase the surface area of the cloth without increasing the size of the cloth (the plane). Trees solve the problem of capturing sunlight in a way that is similar to the brain creating folds: to maximize the exposure of leaves to the sun, the tree creates branches which subsequently create branches and so on. This way, the distance from each leaf to the trunk is limited, while maximizing the amount of sunlight the tree can capture (see Figure 5.9). Objects like these are called fractals (see *Philosophy for Heroes: Continuum*).

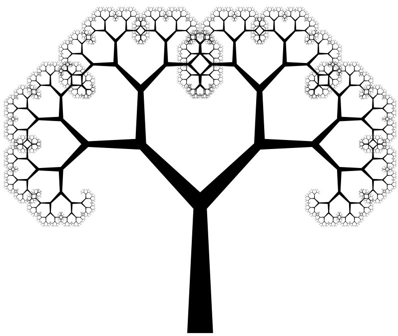

Figure 5.9: This tree-like fractal covers a potentially infinite surface area while limiting the distance from the leaves to the trunk.

[26] Striedter, Srinivasan, and Monuki, 2015.

5.2.3 The Rise of the Humans

How could larger brains have helped early humans to survive? After all, we apply most of our intelligence to utilize complex language and tools. But those things were not available to early humans. And compared to other mammals, even compared to apes, humans are neither strong nor fast, we do not have body armor, we do not have claws or poison, we do not have wings or a strong sense of smell, and we cannot see well at night. At the same time, larger brains meant a higher energy need. In that regard, the question of how human intelligence evolved looks like another chicken-and-egg problem similar to the question of the origin of life (see *Philosophy for Heroes: Continuum*). We need to find an evolutionary path of incremental genetic changes, benefiting our ancestors at each step.

We have become a complex product of nature because our ancestors had to adapt and re-adapt again and again to ever-changing environments. Compare that to lifeforms that have not changed significantly for hundreds of millions of years: they have found a niche in which there was no evolutionary pressure to adapt to new challenges.

The important lesson is that evolution does not work in a directed way where all lifeforms become smarter over time. Brains are simply an adaptation to very specific problems. Each part of our brain addresses a particular need to process information in order to give us an edge over our predators and prey.

Hence, one approach to the question of how humans have diverged from other primates is to think about the influence of the *environment* on our ancestors' evolution. The split from the chimpanzees four million years ago probably happened between those of our ancestors staying in the forest and those going out into the savannah. As trees provided protection and sources of food, it is possible that the savannah was not their first choice. Perhaps a change in geology or climate caused the forest to recede. Later, population growth might have driven our ancestors out into the savannah; this is the *savannah hypothesis.*

> **SAVANNAH HYPOTHESIS** · The *savannah hypothesis* states that early humans evolved on the savannah and that many of the modern human's traits are a result of this adaption.

While the precise sequence of events is still debated—more recent evidence points to a much less abrupt transition from forest to the savannah[27]—the following traits were conducive for early humans to survive in the savannah:

Fire and cooking. Fire allowed early humans to be more active at night. It provided warmth and helped to fend off predators. With the ability to control fire, early humans were able to cook food. This reduced the time needed for digestion compared to eating raw foods, freeing up energy for the brain. While in other apes, the colon represents about 50% of gut volume, in humans, it is less than 20%.[28]

Bipedalism. Bipedalism probably developed before our human ancestors moved into the savannah. After all, apes are able to walk on two feet; they typically choose not to do so. Their muscle configuration makes walking less energy-efficient when compared to humans—just like we *could* walk on our hands, but it takes far too much energy.[29]

Endurance. Better muscle control due to the larger motor cortex (see Chapter 5.2.1) allowed our ancestors to travel longer distances —a very advantageous trait for living on the savannah.

[27] Domínguez-Rodrigo, 2014.
[28] Furness, Cottrell, and Bravo, 2015.
[29] Sockol, Raichlen, and Pontzer, 2007.

Cardiovascular system. We see additional optimization toward endurance in our heart which has adapted for moderate-intensity activity like walking, hunting, or farming. (By contrast, chimpanzees' hearts are optimized for short bursts of intense activity such as climbing and fighting).[30] This enabled our human ancestors to cover greater distances in the savannah, spreading their genes with tribes farther away. And while we cannot run faster than a cheetah in a sprint, we can outrun it in any hunt longer than a mile. Cheetahs are all about sneaking close to their prey and then sprinting toward it in one short burst.

Sight. In the forest, chimpanzees' main visual focus is spotting details. The global image of the forest as a whole is less important than identifying, for example, a snake, or fruits, or another chimpanzee hiding among the leaves. By contrast, the focus of humans adapted to a life in the savannah is a more comprehensive, global image. To coordinate a hunt, you need to keep your entire environment in mind and create a plan for how to approach prey from different directions. Studies have shown that humans are much better than other primates at integrating local visual information into a global whole.[31] Also, being on watch for predators or coordinating a hunt requires humans to constantly scan all directions. The anatomy of our eye sockets gives us a wider field of view compared to that of chimpanzees.[32] This is also more economical as we have to move only our eyes rather than our entire head.

Ranged weapons. It takes precision and perseverance rather than explosive strength when looking at an animal from a distance, feeling the wind, taking a wooden spear, calculating which of the dozens of muscles to stretch and release and in what sequence so that the stick hits its target, and then tracking the wounded animal over hours. In order to throw accurately, the brain has to calculate

[30] Shave et al., 2019.
[31] Denion et al., 2014.
[32] Imura and Tomonaga, 2013.

a sequence of nerve pulses to coordinate which of the hundreds of muscles should contract and in what order. To maximize the impact of a throw, the muscles have to work in harmony, just as performers in an orchestra play various instruments and create a harmonious sound. The comparison between throwing a spear and playing music is fitting as the same regions of the brain are used to produce both. While ranged attacks can be found in nature (tongues of chameleons, other primates throwing sticks and stones, archerfishes spitting water at bugs, pistol shrimps "shooting" air, jumping spiders jumping at their prey), humans are the *only* animal in nature to accurately throw things at long distances.

Language. Building a sentence requires advance planning and coordination. We need to use words in a specific order to carefully construct the sentence rather than trying to exert ourselves in one loud call. This uses the same mental machinery that is required to accurately throw. The *cognitive trade-off hypothesis* explains this difference between chimpanzees and humans by stating that our human ancestors exchanged (some of) their short-term memory for other abilities like abstract language and planning. Evidence for this is in (compared to chimpanzees) humans' significantly larger *angular gyrus* (see Chapter **??**), which helps with tool use, reading, and language.[33] It is also home to our working memory (at least the phonological memory), which is superior in humans compared to chimpanzees.[34]

Reaction time and memory. While humans indeed require short-term memory for conversation, remembering telephone numbers, and reading, only a minimum amount is needed. Not only is a conversation—compared to the snap decision a chimpanzee has to make—stretched out over an extended period of time, but there is also always the possibility of asking questions.

[33] Fjell et al., 2013.
[34] Read, 2008.

Our ancestors in the forest faced a situation very different from those who went out in the savannah. In the forest, with trees blocking their line of sight, they had less time to react to sudden encounters with predators (or rivals). At the same time, they could use the trees to flee from their predators. This adaptation to quickly evaluate and react to a situation seems to be reflected both in today's forest-dwelling chimpanzees' strength as well as in their (compared to humans) superior short-term memory capacity. Experiments have shown that some chimpanzees need only 0.21 seconds (compared to humans needing at least 0.65 seconds) to remember the position and sequence of nine numbers on a computer screen.[35] This is similar to what a chimpanzee might encounter in the wild: imagine nine rival chimpanzees showing up. For the one chimpanzee defending itself, each second spent determining whether to flee to the trees or to prepare to fight might determine whether or not the chimpanzee loses territory, is injured, or even killed.

Games. Language also allows more educational *play.* While other animals (for example dogs or their puppies) have ways of signalling they want to play-fight, humans can develop much more complex games (e.g., hopscotch, fencing, martial arts, soccer, chess, etc.) to allow them to train their mental and physical abilities.[36] We can even use play productively: for example, we train people to operate in space while they are still safely on Earth.

Complex tool use. The mental machinery required to process language also allowed us to create complex tools. Sentences consist of subjects, objects, verbs, adjectives, and adverbs that connect with or modify each other. Similarly, tools consist of different objects that need to be connected. If you can imagine sentences that describe how entities interact with each other, you can imagine tools consisting of entities interacting with each other. Indeed, we can rely solely on language to describe the production of, for example,

[35] Inoue and Matsuzawa, 2007.
[36] Kerney et al., 2017.

a hand-axe or spear. While tool use is not something unique to humans, we have seen only a few examples in the animal world. For example, some monkeys have learned to dry certain nuts, and then later use specific stones to crack them open—a skill that can take years to learn properly.[37] But monkeys are probably not able to create something as complex as a bow and arrow (see Chapter **??**).

Weapon evolution. Over time, our ancestors developed better and better weapons. For example, they added a sharp stone for additional weight, impact damage, and flight properties, and thus, invented the stone-tipped spear. Accurate ranged weaponry offered significant advantages to our ancestors. Not only did they become better at hunting, but also the prey's own defensive weaponry including hooves, claws, and fangs became useless against humans who were no longer within reach. Archaeological evidence puts spear use by our ancestors at as early as 500,000 BC.[38] This led to prey animals becoming more cautious. Individual animals that were more anxious had an evolutionary advantage over more courageous or curious animals. Thus, with each generation, they tried to stay farther away from anything that resembled a human. This put evolutionary pressure on humans to produce better and better tools, throw farther, and invent increasingly intricate hunting techniques and strategies. This created a predator-prey dependency. Like the evolution of the eye (see *Philosophy for Heroes: Continuum*), improvements in our ability to make and throw projectiles brought us an advantage at every step of the way.

Self-domestication. Chimpanzees are much more aggressive than humans, but they are also more hesitant to go into a fight, given that it comes with a significant risk of injury. Humans, on the other hand, evolved the ability to attack from a distance, attack together with others, and even to plan an attack in advance. This put anyone at risk, no matter his or her status. Anyone could be challenged as

[37] Luncz et al., 2017.
[38] Wilkins and Chazan, 2012.

long as there was support from other members of the tribe. This led to significant changes within tribes of humans: the most aggressive or anti-social members of the tribe could be singled out more easily. Just like we domesticated wolves by selecting the least aggressive pups from a litter, humans self-domesticated by removing the most aggressive members of their tribe. While (for the most part) peaceful *within* the tribe, humans became efficient hunters for everything outside of their tribe. We still have to grapple with this dual nature of humanity—sharing a strong sense of community, while also expressing an "us versus them" mentality. On the one hand, we can easily make peace with the people around us; on the other hand, we can *rationalize* (by mentally degrading them) killing animals and killing humans from other tribes. While we might look down at chimpanzees for their in-the-moment aggression and impulsivity and see ourselves as the pinnacle of evolution, we also have to remember how easily humans can suppress their empathy once they have judged someone as "sub-human."

Interestingly, studies have shown that in mammals, certain genes regulate both aggressivity and aspects of anatomical features of the face. This genetic connection explains why we have shorter faces and smaller teeth compared to our primate cousins. Similarly, many domesticated dogs look less threatening than wolves. If our ancestors did not specifically breed wolves, it is conceivable that the least aggressive (and thus also least aggressive-looking) wolves were able to approach a human camp without being attacked by humans. A connection between behavior and facial structures can also be seen in humans. People who are missing a copy of the BAZ1B gene have the *Williams-Beuren syndrome* and are more talkative, outgoing, and less aggressive. They also have rounder faces with shorter noses, full cheeks, and wide mouths with full lips. Vice versa, people with additional copies of the BAZ1B gene (the *7q11.23 duplication syndrome*) tend to be aggressive, have difficulties socializing, and their facial features are also affected.[39]

[39] Zanella et al., 2019.

Rules and laws. Over time, human civilization has replaced the lethal way we deal with aggressive members of our tribes with methods of coping with our emotions: culture, customs, rules, and ultimately, laws. Those of our ancestors who were able to reflect upon their own status and position within society, and how it might feel to be another member of society, ultimately prevailed. As the anthropologist Richard Wrangham put it, "Those who followed the rules were favored by evolution."[40]

Compared to our primate cousins, humans are actually *much less* eager to change the pattern of how they carry out a task.[41] In a study, the participants—humans, rhesus macaques, and capuchin monkeys —had to select three icons in sequence to score a point (or get a banana) in a set of 96 trials. The third symbol showed up once the first two were selected in the correct order. In the second set of the trials, the third symbol showed up immediately; participants could either select all three symbols in order or select only the third symbol to get the reward directly. Most monkeys switched to the more efficient strategy of selecting the third symbol without delay, while humans tended to stay with their previous strategy. Preference for the familiar over a new approach was also confirmed in a second study comparing humans with chimpanzees.[42]

Protected childhood. Compared to babies of other mammals, human babies are totally dependent on their parents. This becomes obvious when comparing human babies to chimpanzee babies: without their mother, human babies are helpless, while chimpanzee babies are at least able to follow or hold onto their mother from early on. Intelligence-wise, human children catch up with chimpanzee children only at the age of one or two years. This is because the brain of a human baby continues to proliferate after birth; by contrast, in terms of growth, chimpanzee brains level off very soon after

[40] Wrangham and Grolle, 2019, cf.
[41] Watzek, Pope, and Brosnan, 2019.
[42] Pope et al., 2020.

birth. We should not look at prolonged childhood being an evolutionary mishap or obstacle, though. Instead, it is more a testament to the success of human parents to provide the necessary protection and nutrition during the earliest periods of their children's lives. It is an expression of the long-term *investment* into the brain development of the child.

Giving a baby the safe space to develop his or her brain without the need to survive independently gives humans an evolutionary edge. It is easier for the brain to put down new neural pathways in a part of the brain that is not being used at the time, just like it is easier for a construction company to replace rail tracks when no trains are using them. We have to keep in mind that we cannot just shut down our brain for a few days for architectural changes. While some cleanup processes happen during our sleep, we still have to be ready to respond within seconds when being awakened by, for example, the sound of a possibly dangerous animal or another human. The requirement to care for our children seems to be another evolutionary factor driving our longevity. As grandparents, we can spend resources on caring for our grandchildren or other relatives. This is not exclusive to humans; it has been shown that among killer whales, post-menopausal whales provided significant survival benefits for their grand-offspring.[43]

With our evolutionary history in mind, let us now take a closer look at the most complex part of our brain, the *neocortex.* In Chapter 5.3, we will look at how the brain processes sense data, while in Chapter **??**, we will cover how the brain initiates and executes movements. Taking everything together, we will examine how the brain can recognize itself in the mirror in Chapter **??**. Once we understand the brain parts involved in the input of sense data and output of motor actions, we can then proceed in Chapter **??** with the central topic of this book, consciousness.

[43] Nattrass et al., 2019.

5.3 A Glimpse into the Brain

How does the brain perceive its environment?

To grasp the brain's underlying functionality, it is best to look at how information flows through individual parts of the brain. While we have already discussed some aspects of the visual cortex, let us revisit it in more detail to see how different systems in the brain interact.

> **LOBE** · A *lobe* is an anatomical division or extension of an organ.

> **OCCIPITAL LOBE** · The *occipital lobe* is part of the *neocortex* and contains the *visual cortex* which is responsible for processing visual sense data.

> **CEREBRAL HEMISPHERES** · The *cerebral hemispheres* consist of the *occipital lobe*, the *temporal lobe*, the *parietal lobe*, and the *frontal lobe.* The two hemispheres are joined by the *corpus callosum.*

Figure 5.10 shows the architecture of the visual system.

- **Right visual field:** Light from the right visual field hits the left sides of the retinas of each eye.
- **Left visual field:** Light from the left visual field hits the right sides of the retinas of each eye.
- **Left retina sides:** Sense data from both left retina sides are communicated through the optic chiasm and combined in the *visual cortex* of the left cerebral hemisphere of the *occipital lobe.*
- **Right retina sides:** Sense data from both right retina sides are combined in the visual cortex of the right cerebral hemisphere of the occipital lobe.

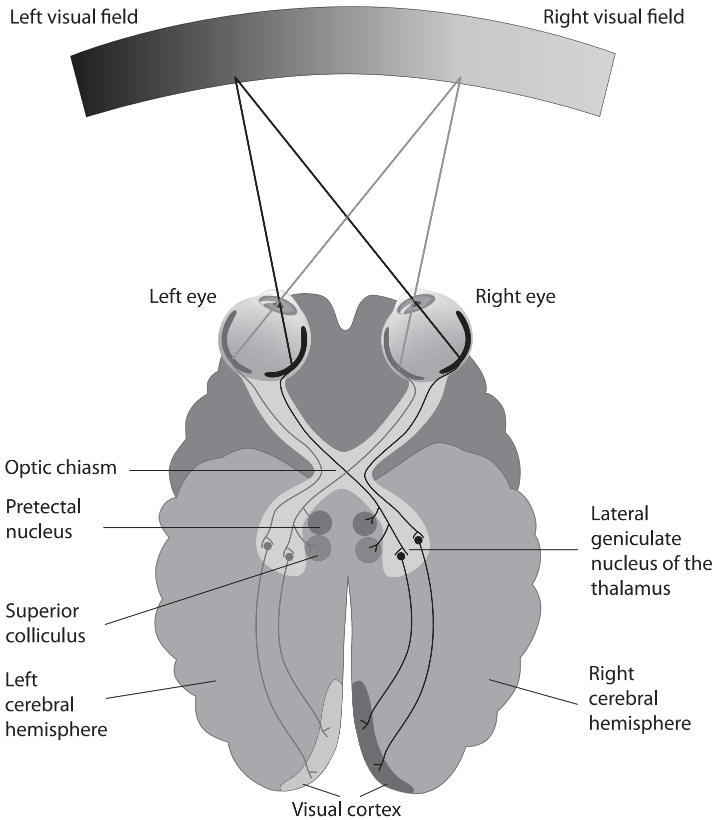

Figure 5.10: The basic visual projection pathway from our eyes to our neocortex. The eyes' lenses project light onto the retinas of each eye. There, light-sensitive cells translate light into electrical impulses. The left side of the projected image is sent to the right hemisphere, and the right side of the projected image is sent to the left hemisphere (image source: Shutterstock).

Ultimately, information from the right visual field is processed in the left visual cortex, and information from the left visual field is processed in the right visual cortex. Between the optic chiasm and the visual cortex, the signal passes through the left and right lateral geniculate nucleus. There, the sense data is pre-processed and transferred to various brain parts, with the visual cortex the most important one. Pre-processing means that the brain analyzes the images and modifies them for further processing by other brain parts.

There are a number of possible reasons evolution led to this rather convoluted architecture where the optic nerves of both eyes cross in the optic chiasm and split the information from the eyes' left and right visual fields. If the left eye were directly connected with the left visual cortex and the right eye directly connected to the right visual cortex, losing one eye would mean that one visual cortex would either no longer receive any input, or it would receive the input too late because it first had to be transferred from the other hemisphere. The crossing in the optic chiasm enables the visual system to work even in the case when only one eye functions properly.

5.3.1 Color Perception

To understand vision, we first need to understand color and light. Light rays are actually electromagnetic waves. Depending on the length of the waves, we experience them as different colors on the color spectrum (so-called spectral colors, see Figure 5.11). To perceive colors, our eyes have photoreceptor cells sensitive to red, green, and blue light (see Figure 5.12). In addition, shorter wavelengths activate both the red and blue photoreceptor cells, making them look purple.

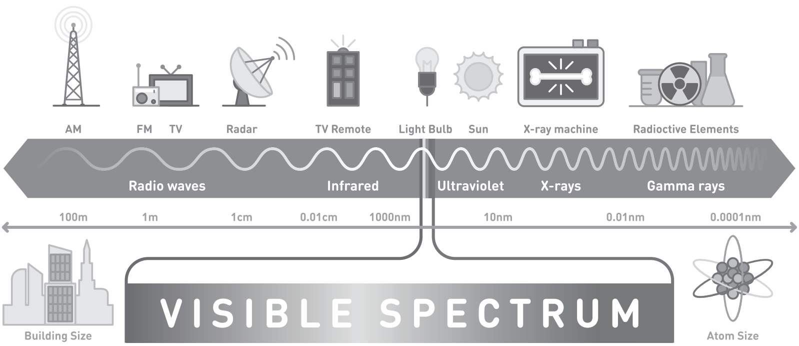

Figure 5.11: The electromagnetic spectrum (image source: Shutterstock).

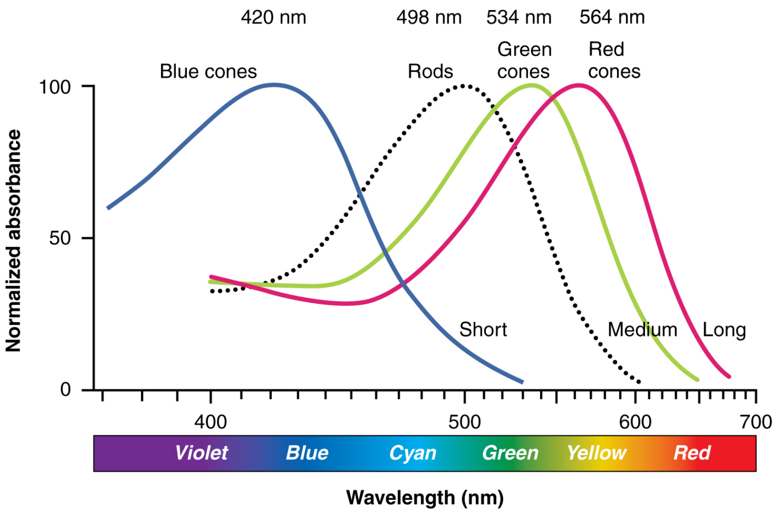

Figure 5.12: Sensitivity of the cones and rods differs depending on the wavelength (image source: Openstax, Rice University).

Now, imagine throwing a stone into a lake. Depending on the size of the stone, water waves of different size will emerge. A large stone will lead to long water wavelengths, a small stone will lead to short water wavelengths. If you threw multiple stones into the water, there would still be water waves, but they would overlap with each other. Just like no single stone can create such an overlapping of water waves, no single light source can create all the colors we can perceive. This is why beyond the colors on the electromagnetic spectrum, we also experience *extra-spectral colors* like white, gray, black, pink, or brown when different photoreceptor cells are activated in combination (see Figure 5.13). Those colors could be compared with multiple stones thrown into the water. For example, a pink flower reflects red light waves, but also reflects green and blue light waves. Similarly, white, gray, and black are the product of different wavelengths at the same intensity, and brown is simply orange at low light intensity.

Red	**Green**	**Blue**	**Interpretation**
100%	0%	0%	red
0%	100%	0%	green
0%	0%	100%	blue
100%	100%	100%	white
50%	50%	50%	gray
0%	0%	0%	black
100%	75%	80%	pink
100%	60%	0%	orange
75%	20%	0%	brown

Figure 5.13: A translation of the activated photoreceptor cells to the subjective experience of color.

That extra-spectral colors are a combination of different wavelengths of light was not discovered until Newton's famous prism experiment in 1666. Before that, it was thought that prisms *produce* colors, but it was Isaac Newton who showed that a prism merely *splits* light into its spectrum. By adding a second prism, Newton proved that the red light from the first prism produced only red light in the second prism, and that he could recombine different colors of light back into white light (see Figure 5.14). This experiment became a symbol for the Scientific Revolution because it replaced a subjective understanding of light with objective, observable facts. The existence of extra-spectral colors show that our subjective experience of the world is pre-processed. The LGN integrates the information from the retina into color information. For example, if we look at a purple van, our red and blue photoreceptor cells are activated. But no matter how close we get to the van, we never see separate blue or red color elements. What we see is pre-processed for us through the combination of different sources of sensory information into new data, the color purple.

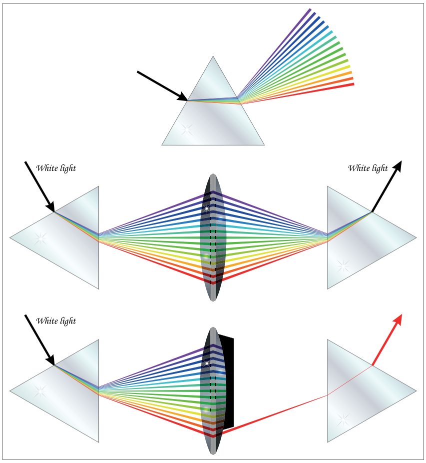

Figure 5.14: Newton's experiment that demonstrates how white light actually consists of light of different colors (image source: Shutterstock).

More complex processing involves the inclusion of the three-dimensional data the LGN has derived from sense data. It is used to further modify the way the LGN integrates color perception. Consider the checkers shadow illusion in Figure 5.15: while in the first picture it looks like a checkerboard with a three-dimensional black ball throwing its shade over the board, the second picture shows how both marked squares were printed (or are displayed) with the identical shade of grey. Our brain processes the image to give us the impression of how the checkerboard would look without the shadow. Without this processing, it would look like the shadow was actually printed on the checkerboard.

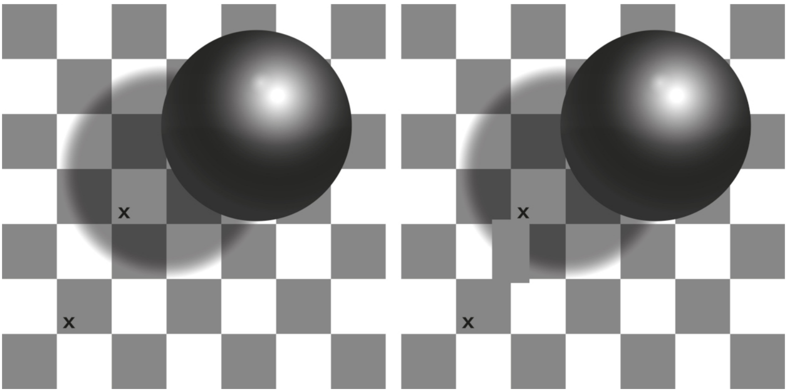

Figure 5.15: The checkers shadow illusion misleads the viewer into thinking that the two-dimensional image of a three-dimensional checkerboard is evenly colored black and white. The second image shows that the squares inside and outside the shadow are identical in color (image source: Shutterstock).

5.3.2 The Brain as a Prediction Machine

Processing visual and auditory data requires time. Studies have shown that the brain needs around 190ms for visual stimuli and 160ms for auditory stimuli.[44] This poses a significant problem: any decision the brain makes is calculated based on old information. A delay of 190ms does not sound like very much. But imagine a ball that is thrown at you with a speed of 100km per hour (or about 15 meters per second). In 190ms, the ball travels a distance of around five meters. With that delay, you would always catch the ball too late. This problem becomes even more complicated if you are moving. To deal with this delay, the brain tries to predict the positions of where objects will be in the near future based on their current speed. This helps other parts of the brain to make more accurate decisions, for example, catching the ball in the right moment.

There are a few instances where this prediction process of the brain fails noticeably. Consider the *Hering illusion* in Figure 5.16: the straight lines near the central point appear to curve outward. Our visual system tries to predict the way the underlying scene would look in the next instant if we were moving toward its center. The cost of predicting the future to reduce reaction times is that we sometimes experience this correction as an optical illusion.[45]

While we can establish that optical illusions are the product of preprocessing and ultimately useful for us, the question is *why* there is a difference between how we *experience* what we see and what is actually there. One could argue that it is just an optimization or filter by the brain for specialized applications (movement, 3D, faces, and so on). But this does not explain why this optimization feels *real* to us, even when we have evidence to the contrary.

[44] Welford, 1980.
[45] Changizi et al., 2008.

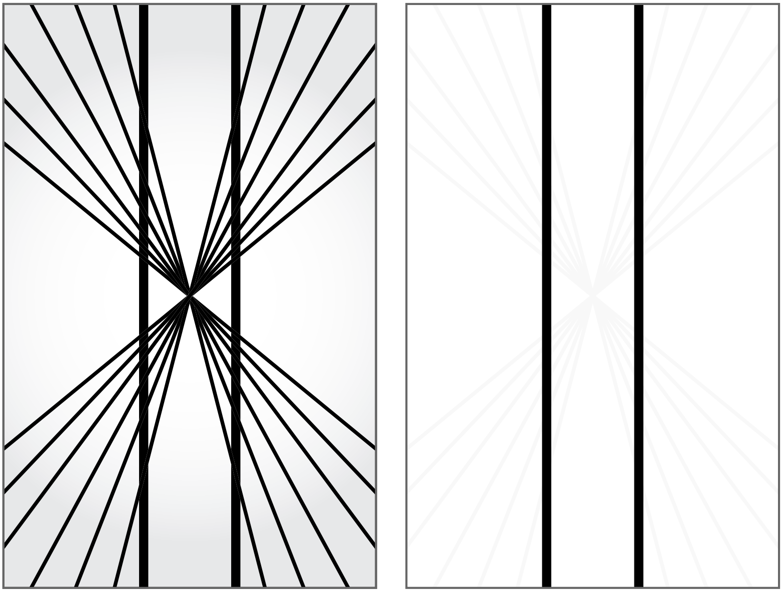

Figure 5.16: Two parallel lines look skewed when the mind is given a spatial context (image source: Shutterstock).

5.3.3 The Ventral and Dorsal Streams

The output from the visual cortex continues as two separate data streams:

- The ventral (lower) stream (the *what*) through the temporal lobe (see Figure 5.17).; and
- The dorsal (upper) stream (the *where* and *how*) through the parietal lobe.

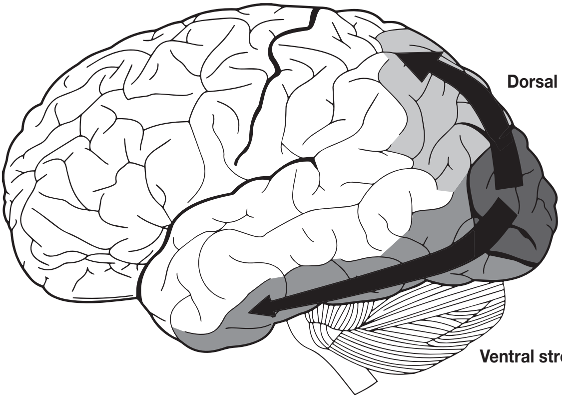

Figure 5.17: Image showing the ventral stream (the *what*, at the bottom through the temporal lobe) and the dorsal stream (the *where* and *how*, at the top through the parietal lobe) in the human brain visual system (image source: Selket, Wikimedia).

The *temporal lobe* processes visual information to categorize *what* things are, while the *parietal lobe* integrates the spatial information into a map of *where* and *how* things are. For example, looking at an apple on a table, the temporal lobe identifies that there is an apple and a table, and the parietal lobe identifies that the apple is on top of the table.

> **Temporal lobe** · The *temporal lobe* is the part of the neocortex that deals with the “what”: long-term memory, and object, face, and speech recognition.

> **Parietal lobe** · The *parietal lobe* is the part of the neocortex that deals with the “where,” especially the location of entities, the “how,” as well as touch perception.

Compared to the dorsal stream, the ventral stream is processed more quickly. It is more important to know what you see (a tiger, a fire, an acquaintance, etc.) than where it is. This idea of prioritization of the processing of the sense data can also be found in the general architecture of the visual system.

One could ask why our visual cortex is at the very back of our brain given that it takes valuable time for a signal to pass through the brain. Why not have all visual processing at the front or at least directly behind the eyes? Given the actual architecture, processing in the visual cortex seems to have a low priority. It is furthest away from the eyes—the opposite of what we would expect from an organ that can require an immediate response.

Looking at it from an engineering point of view and turning the question around, we would ask: what essential functions of the visual system should be put at the front? That is, reflexes to close your eyelids to protect your eyes, to combine information from your left and right eye, to turn your head to a source of movement or sound, to focus your lenses, and to constrict your pupils to protect your retina. All brain parts responsible for these abilities are positioned around the superior colliculi near the eyes. They provide us with reflexes and mechanisms to protect the eyes and refocus them.

After the initial processing in the superior colliculi, the processing goes through the LGN. There, a three-dimensional representation of the world is created, with just enough detail to allow for quick —possibly life-saving—reactions. For example, in a ball game, if we always had to first conceptualize that a ball is flying at us and plan for its arrival, our reactions would be very slow. Learning to catch a ball requires us to bypass conceptualization and just "do"—trusting our instincts supported by early calculations in the LGN before the information even reaches our visual cortex.

5.3.4 The Temporal Lobes

The temporal lobes of the cerebrum are positioned on the left and right side of the brain, near the ears. They process auditory signals and are responsible for identifying *what* is being said (or seen, as part of the ventral stream). Not only does this brain part identify what you see, but it also maps it to language (in *Wernicke's area* of the left temporal lobe). If Wernicke's area is damaged, you would use *individual* words correctly, but in combination, the words may not make any sense.

> **WERNICKE'S AREA** · *Wernicke's area* is located in the left side of the temporal lobe. Its function is the *comprehension* of speech. Damage to Wernicke's area leads to people losing the ability to form meaningful sentences. It is connected to Broca's area, which is responsible for muscle activation to *produce* speech.

The brain part in the right hemisphere corresponding (homologous) to Wernicke's area deals with subordinate meanings of ambiguous words (for example, "bank" refers to a financial institution but could also refer to a river bank).[46] With the ventral stream, you can identify that you are seeing a tree and connect it to the abstract concept of a tree. It also allows you to map the concept of a tree to the image of a tree or to the sound of the word "tree." As we have learned in *Philosophy for Heroes: Knowledge*, this mapping is ultimately connected to a past experience. In terms of learning languages, we connect a word with the experiences we had when hearing or reading the word in the past. Someone pointed to a tree, said "tree," and we connected sound and image with the concept of a tree. As this suggests, the temporal lobe is essential to processing memories. This is supported by the fact that the temporal lobe is also connected to the hippocampus, providing spatial memory and short-term memory, as well as helping to create long-term memories.

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[46] Harpaz, Levkovitz, and Lavidor, 2009.

Figure 5.18: A basic drawing of a kitchen. Despite most of the visual information (textures, colors) being stripped from the image, we can immediately classify it correctly (image source: Shutterstock).

One could argue that a comic strip is the brain's internal representation of what is left after the brain has processed an image—just like the word "tree" is a representation of a real tree. To conceptualize the environment, the brain tries to strip all superfluous information from an image.[47] For example, Figure 5.18 shows a simplified drawing of a kitchen. We can immediately recognize it as a kitchen. Abstract symbols that are stripped of all superfluous information (colors, textures, etc.) are even *easier* (especially with less ambiguity) to recognize, hence their use in street signs.

[47] Morgan, Petro, and Muckli, 2019.

5.3.5 Facial Recognition

Given that we can remember thousands of faces despite them differing only minimally, it is no surprise that we have specialized mental machinery specifically for faces or face-like structures. The temporal lobe contains the *fusiform face area* that deals only with identifying faces. People who lack this ability of the brain to pre-process faces have prosopagnosia ("face-blindness"). Imagine that everyone you meet is wearing a mask: you would have to remember what clothes someone usually wore, how her voice sounded, and categorize people by their hairstyle, height, or body type. Similarly, if we have not encountered enough people from a particular background (Asian, African, European) to have learned to distinguish her facial features, we might have difficulties recognizing individual differences.

Our face recognition is so important that it goes as far as seeing faces where there are none. For example, a standard American power outlet is just that, a power outlet (see Figure 5.19). We are "projecting" that it is a surprised face, although we are absolutely sure that there is certainly not a (human) face in the wall. It seems that we share this ability to recognize basic facial features (two circles and a mouth) at least with reptiles, going back more than 300 million years in our evolutionary history.[48] Looking for faces everywhere can help us to quickly recognize a friend (or enemy)—at the low cost of identifying faces when there are none.

[48]Versace, Damini, and Stancher, 2020.

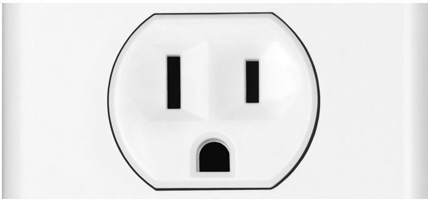

Figure 5.19: A standard American power outlet, which looks like a surprised face (image source: Shutterstock).

The downside of this pre-processing is that we can have a harder time focusing on details of a (known) face. The "Thatcher effect" is a demonstration of this. Looking at Figure 5.20, you can see a young woman's face with a neutral expression. But turn this book upside down, and you will see a woman with a creepy grimace. This is because your ability to recognize faces is optimized to recognize people standing on their feet rather than hanging upside down from a tree. For the neural networks our brain uses, it would take extra effort to check whether or not mouths and eyes are oriented in the right direction. People with prosopagnosia are affected by the Thatcher effect, too, as their only struggle is with the classification of the face as a whole. They still use the same machinery as people without prosopagnosia to classify individual facial features (like the eyes or mouth). It is like the opposite of not being able to see the forest for the trees: we get the meaning of something ("this is a face of a young woman") but miss the details ("her eyes are upside down").

The *extrastriate body area* and the *fusiform body area* are similar to the fusiform face area. They are located in the visual cortex near the fusiform face area and deal with recognizing body parts and body shapes, and analyzing the relationship of moving limbs. Weaker connection between the extrastriate body area and the fusiform body area can lead to misjudgements of one's own body size and to illnesses like anorexia nervosa.[49]

[49] Suchan et al., 2013.

Figure 5.20: Turn your book upside down to experience the "Thatcher Effect." It demonstrates how our visual system is optimized to recognize people standing on their feet rather than hanging upside down (image source: Shutterstock).

5.3.6 Delusions

Faces are evaluated not just in the temporal lobe but also in the amygdala. If the fusiform face area was not working properly, we would still experience an emotion but would not recognize the face. If there is a problem with the connection between the thalamus and the amygdala, we might recognize a face but would lack the emotional response to the face (see Figure 5.21). This can lead to a *monothematic delusion*, namely the *Capgras delusion*.[50]

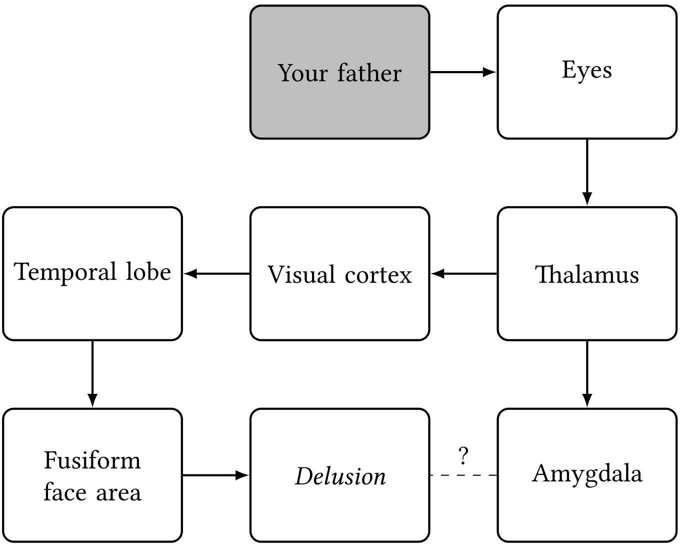

Figure 5.21: If your amygdala does not provide the right emotional information related to a perception, the conflict with the information from the fusiform face area can lead to experiencing the Capgras delusion (in which you assume that the person is an imposter).

[50] Ramachandran, 1998.

> **Monothematic delusion** · A *monothematic delusion* is a delusion focused on a single topic. A delusion is a firm belief that cannot be swayed by rational arguments. It is distinct from false beliefs that are based on false or incomplete information, erroneous logical conclusions, or perceptual problems.

> **Capgras delusion** · A person suffering from *Capgras delusion* can recognize people who are close to him, but he thinks they have been replaced by clones or doppelgangers. One cause for this condition is a damaged or missing connection from the amygdala that leads to a person having no emotional connection to those whom he sees.

The Capgras delusion is the belief that a person emotionally close to you (for example, your father) has been replaced by an imposter. You definitely see that the person is exactly as you have him in your memory; it is just that you no longer feel an emotional connection to him. For the brain, the most apparent (although weird) solution to solve this conflict is to assume that someone is impersonating your loved one. You cannot give clear reasoning for it, but based on the facts (the sense data identifying the person plus the lack of an emotional connection), it is the most logical conclusion. This can also happen in healthy people with movie actors. Having built an emotional connection to the character a person plays, there is a disconnect when meeting the actor in person: the actor looks exactly like the character but the emotional connection to the actor is missing. The best explanation the brain might come up with is that the person whom you are seeing (and who is the actor) is an imposter. This is more probable when meeting the actor outside the usual environment (convention, conferences, movie award events, etc.) in daily life (at the grocery store).

Other noteworthy delusions are:

- Fregoli delusion (all the people you meet are actually the same person in disguise);

- Syndrome of subjective doubles (there is a doppelganger of yourself acting in your name);
- Cotard delusion (you are dead or do not exist);
- Mirrored-self misidentification (the person in the mirror is someone else); and
- Reduplicative paramnesia (a place or object has been duplicated, like the belief that the hospital to which a person was admitted is a replica of an actual hospital somewhere else).

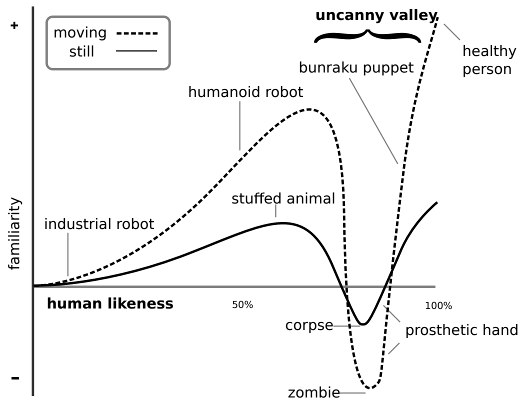

Figure 5.22: The "uncanny valley" effect with human-like dolls or robots (image source: Karl MacDorman).

Somewhat related to delusions is the "uncanny valley effect."[51] We have no problem dealing with dolls. However, when they become too human-like (but not fully human-like), we experience feelings of eeriness and revulsion (see Figure 5.22). This is why zombies (and to an extent, human-like robots) are used in horror movies. Even modern computer graphics artists have serious problems creating believable faces. We can notice the smallest deviation from reality even if the face geometry fully matches the human face. The artist has

[51] Rosenthal-von der Putten et al., 2019.

to hit all the marks when it comes to lighting, mouth movements, nose shadows, skin pore structure, and so on. This is of no surprise as research points to face recognition being highly evolved as it is used also to detect kinship[52] which is an evolutionary advantage in taking care of relatives as well as for mate selection.

> **Uncanny valley effect** · The *uncanny valley effect* refers to the negative reaction to dolls or robots that are very (but not fully) human-like. Possible reasons for this reaction are an inbuilt instinct to avoid corpses, and the inner conflict and discomfort of switching back and forth between seeing a being as fully human or a lifeless object.

The uncanny valley effect is similar to the Capgras delusion in regard to there being two pieces of conflicting information in the brain. One pathway tells you "This is a human!" while another warns "No, that is no human," and the brain has to sort it out somehow, leaving you with a strange feeling of uncertainty. Some of us might have experienced the sudden shock at night when we see a person standing in our living room, only to discover that it is just the clothes rack. The physical presence of a person implies relationships, conflicts, alliances, and enemies. Humans can be more dangerous than the wildest animal, hence anything that resembles a human gets the most immediate attention. In addition, some of the discomfort could also stem from pathogen avoidance (a nearly human-like robot could also be seen as a real human with a serious illness or even as a corpse).[53]

With perception on the one side, we now need to look at consciousness from the other side: action. To act in this world, we need to know that we have a body and know how to use it. We need to differentiate between self and other by creating a so-called "body schema" which we will discuss in Chapter **??**.

[52] Kaminski et al., 2009.
[53] Moosa and Ud-Dean, 2010.

The Book Series
Philosophy for Heroes

> She said, "I will go no farther." "There is no choice. We can only go on." The magician said again. "We can only go on."

—Peter S. Beagle, *The Last Unicorn*

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Recommended Reading

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> What I cannot create, I do not understand.
>
> —Richard Feynman

Glossary

A

Allocortex • The *allocortex* is part of the cerebral cortex (the *neocortex* is the other part) and consists of the olfactory system and the hippocampus.

Amygdala • The *amygdala* is the brain's value and emotion center. It helps with evaluating thought patterns of the basal ganglia depending on the context instead of the mere strength of the signal. It also connects the brain with the hippothalamus, providing a bridge to the hormonal system.

Angular gyrus • The *angular gyrus* combines visual, auditory, and somatosensory information and puts things into relationship with each other. The *left angular gyrus* deals with relationships in the external world, especially relating to words and letters, and the *right angular gyrus* deals with the relationship between the self and the external world.

Attention • *Attention* is the brain's process of limiting alternative thought patterns, then increasing the most dominant thought pattern's strength. It is like a simple majority rule: the most successful thought pattern gets all the resources while other thought patterns are suppressed. While we can jump back and forth between different thoughts, we cannot have two dominant thought patterns at the same time.

Attention schema • The *attention schema* is a model the brain creates of the process of attention. It allows access to the working memory in order to be able to intervene before an action is taken.

Awareness • *Awareness* is a description of the process of attention. Something can grab the attention of your brain, but to talk about it, you need a model of what is happening in your brain. Awareness is such a model.

Awareness schema • The *awareness schema* is a model the brain creates of the process of awareness. With the awareness schema, the brain can write to the working memory to influence what the brain will focus on next. It also allows the brain to imagine alternative, past, or future scenarios.

B

Basal ganglia • The *basal ganglia* are a part of the brain that, like a referee, arbitrate decisions by the neural committees. Also, like an orchestra conductor, they coordinate the sequence of entire motor programs. In both cases, they do not make decisions but merely provide rules and structure.

Blindsight • Someone suffering from *blindsight* reports that he cannot see. However, experiments show that he can react to visual cues. As a result of damage in the visual cortex, information from the retina arrives in the midbrain but does not undergo conscious processing through the visual cortex.

Body schema • The *body schema* is the brain's simplified description of the status of the body. It is built by correlating what we see and feel our body is doing with signals that the brain sends to the muscles.

Broca's area • *Broca's area* is a brain part located in the left side of the frontal lobe and connected to Wernicke's area. It is responsible for the *production* of speech. Damage to Broca's area leads to a person unable to find the words to express what he wants to say. The homologous area in the right hemisphere deals with non-verbal communication.

Buddhism • *Buddhists* (Buddha lived 563–483 BC or 480–400 BC depending on the source) believe in a difference between brain and consciousness, with consciousness being compared to a light that shines on thoughts. The mind dies with the bodily death while "you" are reborn into a new being with no memories of your previous life.

C

Capgras delusion • A person suffering from *Capgras delusion* can recognize people who are close to him, but he thinks they have been replaced by clones or doppelgangers. One cause for this condition is a damaged or missing connection from the amygdala that leads to a person having no emotional connection to those whom he sees.

Cartesian theater • The *Cartesian theater* is a term coined by Daniel Dennett to criticize most of the contemporary explanations of consciousness. At their core, such explanations all share the view that there is some sort of miniature person ("homunculus") or entity within the brain looking at what we are looking at—an idea which ends in an infinite series of subsequently ever-smaller Cartesian theaters with ever-smaller homunculi.

Cerebellum • The *cerebellum* is the brain part that helps with coordination of complex behavior. It provides a set of motor programs the brain can choose from repeatedly for similar actions (even in time-critical situations). With the help of the cerebellum we can, for example, walk or bicycle without having to consciously think of each movement.

Cerebral cortex • The *cerebral cortex* is the outer layer of the cerebrum. It contains most of the neurons of the brain.

Cerebral hemispheres • The *cerebral hemispheres* consist of the *occipital lobe*, the *temporal lobe*, the *parietal lobe*, and the *frontal lobe*. The two hemispheres are joined by the *corpus callosum*.

Cerebrum • The *cerebrum* includes the neocortex (the cerebral hemispheres), and the allocortex (the hippocampus, the basal ganglia, and the olfactory bulb).

Consciousness • *Consciousness* is an umbrella term for the brain's abilities to process sense data, focus on something, be aware of something, have the ability to process high-level information (attention schema), be able to control awareness (awareness schema), and reflect on abstract information (philosophy and science).

Copenhagen interpretation • In the *Copenhagen interpretation* of quantum mechanics, an observer is required for the wave function to collapse. Without observation, the wave function never collapses and never becomes a particle. While the interpretation does not mention consciousness as such (measurements by a device are observations, too), it raises the question of who observes the observer, resulting in an infinite loop.

Corpus callosum • The *corpus callosum* connects the left and right brain hemispheres, coordinating tasks requiring both sides.

D

Declarative memory • *Declarative memory* connects one memory with another. For example, the amygdala maps thalamic sense input to emotions; the hippocampus maps places with each other for orientation; and the neocortex maps concepts with other concepts (a tree is a plant).

E

Emergent property • An *emergent property* is a property of a system that emerges only when its parts are combined or interact with each other. Individual parts of that system do not have the emergent property themselves. For example, the division of labor in ant colonies allows the ants to be more efficient than if individual ants fended for themselves.

Encephalization quotient • The *encephalization quotient* (EQ) is a measure of relative brain size and is often used to convey how small or large a species' brain is compared to that of other species of similar body size.

Episodic buffer • The *episodic buffer* is responsible for remembering the sequence of events, including the last state of an entity.

Evil demon • Descartes' *evil demon* is a thought experiment to differentiate the immaterial mind from the brain. His "evil demon" is an entity that could make any changes to the material world without anyone being aware of such changes. Descartes' assumption was that by examining the remaining things we could rely on, we would discover what the immaterial mind is.

Executive functions • The *executive functions* represent a series of means by which the prefrontal cortex can suppress thought patterns in other parts of the brain. While winners in the neural competition are selected with the help of the basal ganglia, the prefrontal cortex can counteract those decisions in favor of other actions. The prefrontal cortex makes these decisions based on its models. For example, stealing goes against the norms of society, so the prefrontal cortex suppresses the (utilization behavior of the parietal lobe's) urge to grab someone else's property.

F

Frontal lobe • The *frontal lobe* of the neocortex deals with running a simplified simulation of the world. It provides us the ability to plan and evaluate actions and their future impact. The somatosensory area of the parietal lobe is directly adjacent to the frontal lobe.

G

Gyrus • A *gyrus* is a fold or ridge in the cerebral cortex.

H

Hard problem of consciousness • The *hard problem of consciousness* asks the question where the subjective experience of consciousness comes from. It is "hard" as there are no known ways of detecting this experience objectively without relying on the subjective claims of an individual (or ourselves).

Hemispatial neglect • Someone suffering from *hemispatial neglect* lacks consciousness of half of his visual field. The person is not aware that his vision is impaired in any way, making the condition different from blindness in one eye. People with this condition have to learn abstract strategies as a way of coping.

Hippocampus • The brain's *hippocampus* provides us with a mental map for navigation. It also builds temporal relationships between places, allowing us to determine, for example, which areas in our environment we have already foraged and in which areas the plants have regrown. The *hippocampus* and the *olfactory system* (sense of smell) make up the *allocortex*.

Homunculus argument fallacy • The *homunculus argument* is the fallacy of trying to explain consciousness by another (smaller) conscious person (the "homunculus") observing and steering you. The problem with this explanation is that it remains unexplained how this smaller homunculus subsequently experiences consciousness.

I

Indian idealism (Vedanta) • In the *Indian idealist* worldview, there is but a single consciousness and our experience of the world as separate beings or consciousnesses is an illusion.

Intuition • Your initial evaluation of a situation is called *intuition*. It is the first thing that comes to your mind without going through conscious deliberation or reasoning.

L

Lateral geniculate nucleus • The *lateral geniculate nucleus* (LGN) is part of the thalamus and relays information from the retinas (via the optic chiasm) to the visual cortex. It pre-processes some of the information, for example, combining red, green, and blue photoreceptor cells into colors.

Lobe • A *lobe* is an anatomical division or extension of an organ.

Loop of consciousness • The *loop of consciousness* refers to a network of connections in the brain from the thalamus to the cortex, then to the basal ganglia, and then back to the thalamus (also called the *cortico-basal ganglia-thalamo-cortical loop*). It is believed that this is the source of our subjective experience of the world.

M

Many-minds interpretation • The *many-minds interpretation* of quantum mechanics is similar to the many-worlds interpretation, in which the universe splits into infinite universes. In the many-minds interpretation, the split of the universe happens with each thought for each individual brain, instead of with each measurement (as in the many-worlds interpretation). Consequently, one's consciousness splits into many consciousnesses whenever a decision was made.

Materialism • In the *materialist* worldview, there is no separate "mind." Instead, everything can be explained by a single substance (matter).

Mechanistic theory • A *mechanistic theory* is a theory that explains a system as if it were a computer program or a mechanical machine with gearwheels: you can understand it by tracing the input to the output. Pedagogically, a mechanistic theory is of great value as we can explain the essential workings of a system step by step using a diagram with boxes and arrows.

Mind-brain dualism • The philosophical view of *mind-brain dualism* (or also *mind-body dualism* with “body” including our brain) states that what we call the (immaterial) mind is separate from the material world (the body, including the brain).

Mirror test • The *mirror test* evaluates the ability of an animal to recognize itself in a mirror after a researcher has secretly added a blot of coloring to the animal’s body and put the animal in front of a mirror. If the animal starts investigating the blot of color on its own body instead of on the mirror image, it passes the test (because that indicates the animal realizes it is the same creature that it sees in the mirror).

Model • The *model* of an entity is a simplified simulation of that entity. It consists of the entity’s concepts and its properties, as well as some of the entity’s measurements.

Monism • The philosophical view of *Monism* is that everything that exists (including what we call mind or consciousness) can be traced back to a single fabric of the universe. The consequence of this view is that the mind must be a result of a (mechanistic materialist) process and that mind and matter are not two separate things.

Monothematic delusion • A *monothematic delusion* is a delusion focused on a single topic. A delusion is a firm belief that cannot be swayed by rational arguments. It is distinct from false beliefs that are based on false or incomplete information, erroneous logical conclusions, or perceptual problems.

N

Neocortex • The *neocortex* is the newest part of the mammalian brain and consists of the *cerebral hemispheres.* Its main tasks are focus, language, long-term planning, and modelling of the world. It can generate strategies that involve detours if goal-directed behavior is not successful (for example, going around a fence instead of trying to get through it).

Nerve net • A *nerve net* is nervous system without a central organization. This means that any signal (that exceeds a certain signal strength) the nerve net receives through its senses causes a singular reaction. Hydras have this kind of nervous system and use it to contract their body when prey touches their tentacles.

Neutral monism • In the *neutral monist* worldview, while both mind and matter exist, they both stem from a third, undefined substance.

Nocturnal bottleneck hypothesis • The *nocturnal bottleneck hypothesis* posits that many mammalian traits were adaptions to moving into a niche to become nocturnal animals and evade the dominant dinosaurs.

O

Object permanence • The ability of *object permanence* allows us to track predicted positions or movements of objects even after they have vanished from our field of view. By running a simplified simulation of the world, we are aware that a tiger that has jumped behind a tree is still there.

Objectivism • *Objectivism* (founded by Ayn Rand, 1902–1982) is a monist philosophy that recognizes a distinction between the brain and a “prime mover” that has a power of whether to focus the brain or not.

Occipital lobe • The *occipital lobe* is part of the *neocortex* and contains the *visual cortex* which is responsible for processing visual sense data.

P

Parietal lobe • The *parietal lobe* is the part of the neocortex that deals with the "where," especially the location of entities, the "how," as well as touch perception.

Philosophical zombie • A *philosophical zombie* is a hypothetical being that acts exactly like a human but lacks the inner conscious experience. The existence of a philosophical zombie is used as an argument against consciousness being a mechanistic process: if we are but a mechanistic machine, why would we need a subjective, conscious experience? This argument is addressed by pointing out the necessary evolutionary advantage of having a conscious experience, which is the ability to focus and to explain oneself to others.

Phonological loop • The *phonological loop* is an acoustic memory system of the brain that holds spoken words or sounds. It involves (among other brain parts, see Buchsbaum and D'Esposito, 2008) Broca's area and Wernicke's area.

Prefrontal cortex • The *prefrontal cortex* is part of the frontal lobe and can be understood as running a simulation of the world. It monitors social relationships, keeps track of objects when they are no longer visible (object permanence), and helps with the pursuit of long-term goals. It has only indirect connections to brain parts dealing with actions or sense perception.

Premotor cortex • The *premotor cortex* is part of the frontal lobe and prepares motor programs to be executed by the adjacent *primary motor cortex*. It has strong connections to the *superior parietal lobe* which provides a model of the current state of the limbs.

Primary motor cortex • The *primary motor cortex* is part of the frontal lobe and is directly adjacent to the primary somatosensory cortex of the parietal cortex. This way, it can directly process data from our sense of touch to better control movements. The *primary motor cortex* connects to the *brainstem* and *spinal cord* (via the *upper motor neurons*) which in turn connect to the muscles (via the lower motor neurons).

Primary somatosensory cortex • The *primary somatosensory cortex* in the parietal lobe deals with the processing of tactile sense input. Each body part is represented in the primary somatosensory cortex. The size of each representation correlates with the sensitivity of the body part to tactile stimulation (for example, lips and hands have a larger representation than other body parts).

Q

Quantum mind • The term *quantum mind* refers to a collection of theories that consider quantum mechanics as the basis of consciousness.

R

Rubber hand illusion • The *rubber hand illusion* can be evoked by brushing both a fake rubber hand and the real hand of a human participant. If only the fake rubber hand is visible, the brain will assume it is the real hand and incorporate it into its body schema.

S

Savannah hypothesis • The *savannah hypothesis* states that early humans evolved on the savannah and that many of the modern human's traits are a result of this adaption.

Sense data • *Sense data* are informations, converted to a form usable by cognition, about an effect registered by a sensory organ.

Split-brain syndrome • The *split-brain syndrome* can occur when the *corpus callosum* is damaged. This leads to problems with communication between the left and right brain hemispheres and complicates some tasks requiring both sides.

Subjective idealism • In the *subjective idealist* worldview, there is no such thing as "matter." Instead, everything is but perception, mind, or "consciousness," and nothing exists but human minds and gods.

Sulcus • A *sulcus* is a groove in the cerebral cortex.

Superior colliculus • The *superior colliculus* or *optic tectum* (in non-mammals) helps the eyes to track objects, and controls blinking, pupillary, and head-turning reflexes.

Superior parietal lobe • The *superior parietal lobe* deals with creating and maintaining a mental representation of the internal state of the body.

Supervised learning • Using *supervised learning*, a brain (or computer) can improve its response to a situation with each new encounter. For example, a dog can learn to sit or roll over on command by getting positive rewards for doing so during training.

Supramarginal gyrus • The *supramarginal gyrus* (SMG) creates an internal representation of the *limbs* of the body, similar to the adjacent superior parietal lobe (which creates a representation of the *internal state* of the body). It supports tool use (left SMG) and interpreting the emotional state of other people based on their postures and gestures (right SMG).

T

Tabula rasa • *Tabula rasa*, (meaning "blank slate"), refers to the view that we are born without any innate knowledge and that our minds can create knowledge only with the help of sense data.

Temporal lobe • The *temporal lobe* is the part of the neocortex that deals with the "what": long-term memory, and object, face, and speech recognition.

Thalamus • The *thalamus* integrates different sensory information and relays the information to other brain parts. For example, it combines sense data from the retinas' cones into colors, or calculates three-dimensional information from the two-dimensional images from both eyes.

Theory of mind • The concept of *theory of mind* refers to the ability to imagine what other people (or animals) are thinking and what they know. This provides a significant advantage for hunting (predicting whether the prey can see or otherwise sense you), or social interaction (teaching, trading, and even lying, etc.).

Temporoparietal junction • The *temporoparietal junction* is a brain area between the temporal lobe and the parietal lobe, integrating data from the thalamus, as well as the limbic system, and the visual, auditory, and somatosensory systems. Combining the "what" and the "where" information, it creates a distinction between "self" and "other."

Turing test • In 1950, Alan Turing proposed the *Turing test* to assess whether or not a machine is intelligent. In the test, a human participant would observe a text chat between a computer and a human. The machine would pass if the observer could not tell who was the machine and who was the human.

U

Uncanny valley effect • The *uncanny valley effect* refers to the negative reaction to dolls or robots that are very (but not fully) human-like. Possible reasons for this reaction are an inbuilt instinct to avoid corpses, and the inner conflict and discomfort of switching back and forth between seeing a being as fully human or a lifeless object.

Unsupervised learning • Using *unsupervised learning*, a brain (or computer) can build a concept by analyzing several sense perceptions, finding commonalities, and dropping measurements. For example, unsupervised learning could be used to form the concept "table" by encountering several different tables and finding out that they share properties like having a table-top, the form, material, and size of the table-top, and the number of table legs.

U

Viso-spatial scratchpad • The *visuo-spatial scratchpad* is responsible for temporarily storing visual and spatial information (involving the occipital lobes).

Von Neumann-Wigner interpretation • The *von Neumann-Wigner interpretation* of quantum mechanics tries to solve the loop of the Copenhagen interpretation by stating that consciousness is outside of the quantum world and is the final observer that collapses the wave function. For consciousness itself to exist, no observation of consciousness would be needed.

W

Wernicke's area • *Wernicke's area* is located in the left side of the temporal lobe. Its function is the *comprehension* of speech. Damage to Wernicke's area leads to people losing the ability to form meaningful sentences. It is connected to Broca's area, which is responsible for muscle activation to *produce* speech.

Working memory • *Working memory* is the collection of a number of different (limited) short-term memory systems in the brain. The prefrontal cortex has access to the working memory.

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Index

An Important Final Note

Writers are not performance artists. While there are book signings and public readings, most writers (and readers) follow their passion alone in their writing spaces at home, in a café, in a library, at the beach, or at a mountain retreat.

*What applause is for the musician, **reviews** are for the writer.*

Books create a community among readers; you can share your thoughts among all those who will or have read this book.

Please leave a thoughtful, honest review and help me to create such a community on the platform on which you have acquired this book. What did you like, what can be improved? To whom would you recommend it?

Thank you, also in the name of all the other readers who will be better able to decide whether this book is right for them. A positive review will increase the reach of the book; a negative review will improve the quality of the next book. I welcome both!

> “If the human race develops an electronic nervous system, outside the bodies of individual people, thus giving us all one mind and one global body, this is almost precisely what has happened in the organization of cells which compose our own bodies. We have already done it. [...] If all this ends with the human race leaving no more trace of itself in the universe than a system of electronic patterns, why should that trouble us? For that is exactly what we are now!

—Alan Watts, The Book on the Taboo Against Knowing Who You Are