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NGSS Core Ideas: Heredity: Inheritance and Variation of Traits

Presented by: Ravit Golan Duncan

February 25, 2014

6:30 p.m. ET / 5:30 p.m. CT / 4:30 p.m. MT / 3:30 p.m. PT

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Introducing today’s presenters…

Ted Willard
Director, NGSS@NSTA
National Science Teachers Association

Ravit Golan Duncan
Associate Professor of Science Education
Rutgers University

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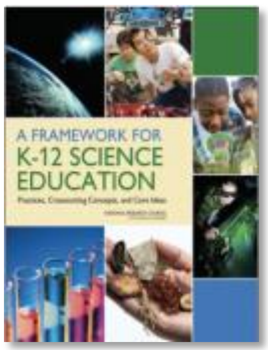

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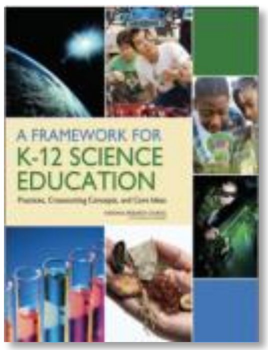

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A Framework for K-12 Science Education

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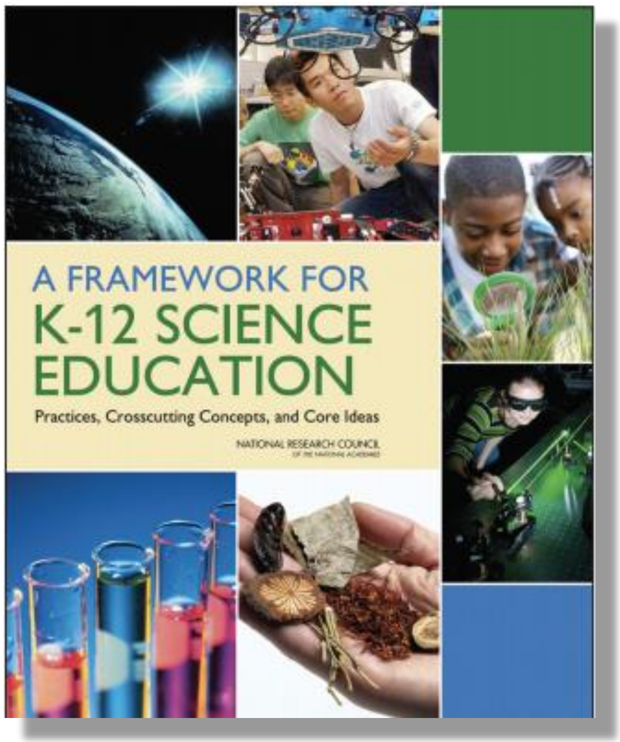

Three-Dimensions:

- **Scientific and Engineering Practices**
- **Crosscutting Concepts**
- **Disciplinary Core Ideas**

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Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

Disciplinary Core Ideas

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Life Science	Physical Science
LS1: From Molecules to Organisms: Structures and Processes LS2: Ecosystems: Interactions, Energy, and Dynamics LS3: Heredity: Inheritance and Variation of Traits LS4: Biological Evolution: Unity and Diversity	PS1: Matter and Its Interactions PS2: Motion and Stability: Forces and Interactions PS3: Energy PS4: Waves and Their Applications in Technologies for Information Transfer
Earth & Space Science	**Engineering & Technology**
ESS1: Earth's Place in the Universe ESS2: Earth's Systems ESS3: Earth and Human Activity	ETS1: Engineering Design ETS2: Links Among Engineering, Technology, Science, and Society

Disciplinary Core Ideas

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Life Science	Earth & Space Science	Physical Science	Engineering & Technology
LS1: From Molecules to Organisms: Structures and Processes LS1.A: Structure and Function LS1.B: Growth and Development of Organisms LS1.C: Organization for Matter and Energy Flow in Organisms LS1.D: Information Processing	**ESS1: Earth's Place in the Universe** ESS1.A: The Universe and Its Stars ESS1.B: Earth and the Solar System ESS1.C: The History of Planet Earth	**PS1: Matter and Its Interactions** PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions PS1.C: Nuclear Processes	**ETS1: Engineering Design** ETS1.A: Defining and Delimiting an Engineering Problem ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution
LS2: Ecosystems: Interactions, Energy, and Dynamics LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycles of Matter and Energy Transfer in Ecosystems LS2.C: Ecosystem Dynamics, Functioning, and Resilience LS2.D: Social Interactions and Group Behavior	**ESS2: Earth's Systems** ESS2.A: Earth Materials and Systems ESS2.B: Plate Tectonics and Large-Scale System Interactions ESS2.C: The Roles of Water in Earth's Surface Processes ESS2.D: Weather and Climate ESS2.E: Biogeology	**PS2: Motion and Stability: Forces and Interactions** PS2.A: Forces and Motion PS2.B: Types of Interactions PS2.C: Stability and Instability in Physical Systems	**ETS2: Links Among Engineering, Technology, Science, and Society** ETS2.A: Interdependence of Science, Engineering, and Technology ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World
LS3: Heredity: Inheritance and Variation of Traits LS3.A: Inheritance of Traits LS3.B: Variation of Traits	**ESS3: Earth and Human Activity** ESS3.A: Natural Resources ESS3.B: Natural Hazards ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change	**PS3: Energy** PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces PS3.D: Energy in Chemical Processes and Everyday Life	***Note**: In NGSS, the core ideas for Engineering, Technology, and the Application of Science are integrated with the Life Science, Earth & Space Science, and Physical Science core ideas*
LS4: Biological Evolution: Unity and Diversity LS4.A: Evidence of Common Ancestry and Diversity LS4.B: Natural Selection LS4.C: Adaptation LS4.D: Biodiversity and Humans		**PS4: Waves and Their Applications in Technologies for Information Transfer** PS4.A: Wave Properties PS4.B: Electromagnetic Radiation PS4.C: Information Technologies and Instrumentation	

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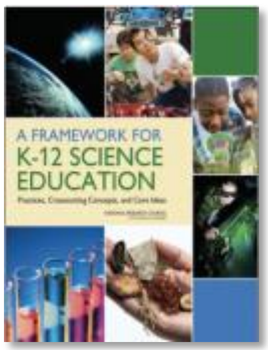

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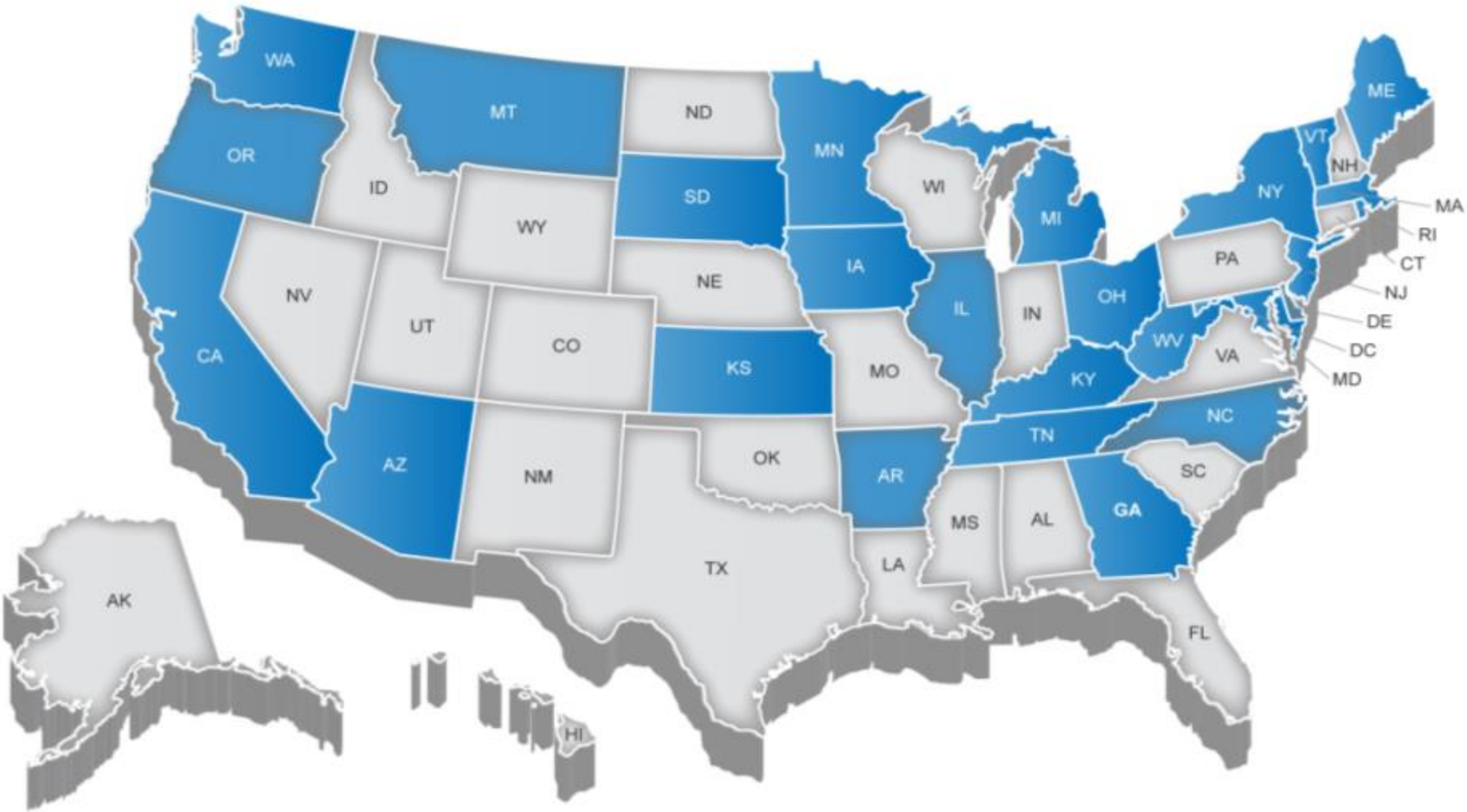

NGSS Writers

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Adoption of NGSS

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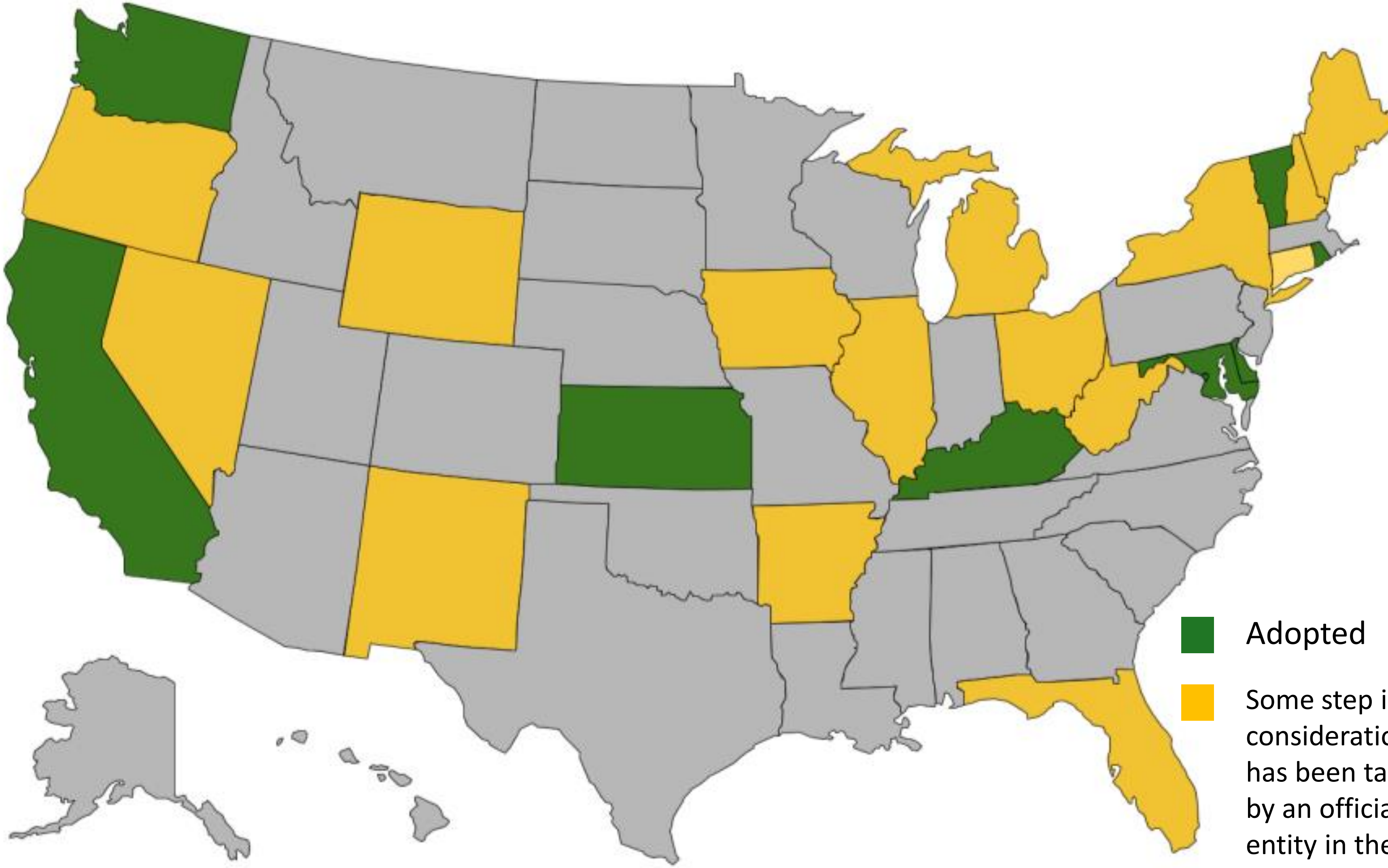

Adopted

Some step in consideration has been taken by an official entity in the state *(from NASBE)*

Closer Look at a Performance Expectation

NGSS@NSTA STEM STARTS HERE

MS-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

MS-PS1-d. Develop molecular models of reactants and products to support the explanation that atoms, and therefore mass, are conserved in a chemical reaction. [Clarification Statement: Models can include physical models and drawings that represent atoms rather than symbols. The focus is on law of conservation of matter.] [Assessment Boundary: The use of atomic masses is not required. Balancing symbolic equations (e.g. N2 + H2 -> NH3) is not required.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems. • Use and/or develop models to predict, describe, support explanation, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-PS1-a), (MS-PS1-c), (MS-PS1-d) --- **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-d)	**PS1.B: Chemical Reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-d), (MS-PS1-e), (MS-PS1-f) • The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-d)	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-d)

Note: Performance expectations combine practices, core ideas, and crosscutting concepts into a single statement of ***what is to be assessed***.

They are not instructional strategies or objectives for a lesson.

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Core Idea LS3: Heredity

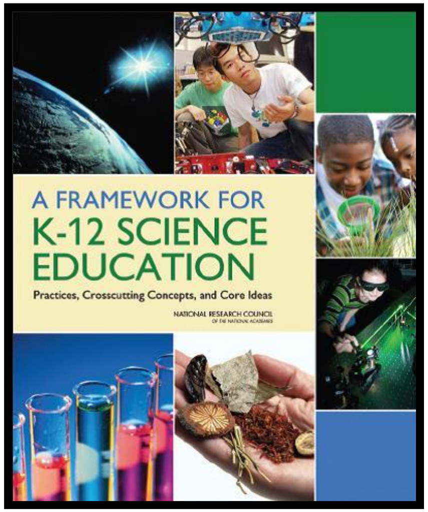
Inheritance and Variation of Traits

Ravit Golan Duncan

Rutgers University

Who am I?

- Learning Scientist and Science Education researcher
  - Joint appointment at the School of Education and the School of Environmental and Biological Sciences
- Study student learning in genetics at the middle, high school, and college level
  - Learning progressions in genetics- how big ideas develop over time
- Reviewer of the NRC framework



Poll: Who are You?

Grades K-2

Grades 3-5

Middle School

High School

Please place a mark next to the grade/s you teach

Overview

- **LS3: Heredity, why is it a core idea?**
  - LS3A: Inheritance of traits
  - LS3B: Variation of traits

Q&A

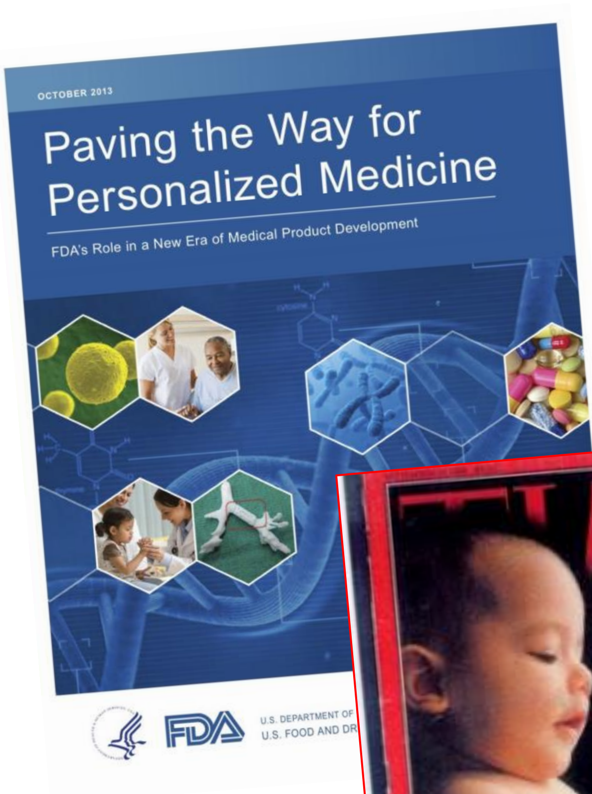
- **Progression of LS3 across grade bands**
- **Student difficulties in mastering this core idea**

Q&A

- **Effective teaching strategies and resources**
  - Integration of science practices and LS3

We will also have a few poll questions along the way

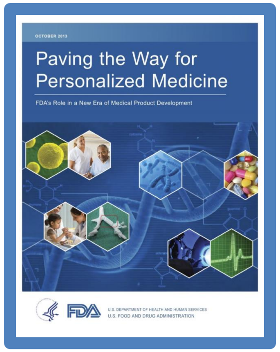
Why is Heredity a DCI?



Why is Heredity a DCI?

Genetics is to biology what atomic theory is to physics… John Stephen Jones

- **Organizing idea in biology**: helps explain other theories (evolution)
- **Powerful and generative:** allows you to explain a wide array of phenomena
- **Relevant:** individuals encounter genetics in many everyday contexts
  - Critical component of scientific literacy for both personal and civic engagement



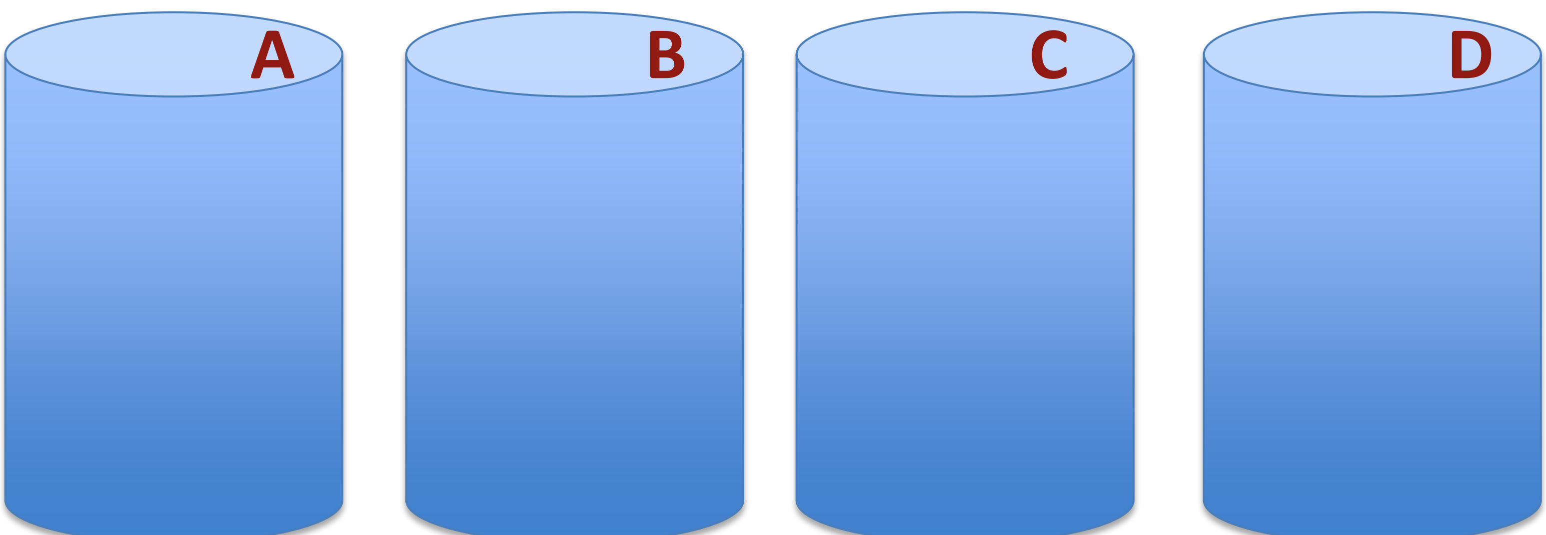
Poll: Genetic Phenomena

Which of the following is a real genetic phenomenon: (use pencil to select all that apply)

A. Resistance to HIV **B**. Glow in the dark cats

C. Genetic males [XY] that look like females

D. Flies with eyes on their legs



Poll: Genetic Phenomena

Which of the following is a real genetic phenomenon:

A. Resistance to HIV
B. Glow in the dark cats
C. Genetic males [XY] that look like females
D. Flies with eyes on their legs

They ALL are!

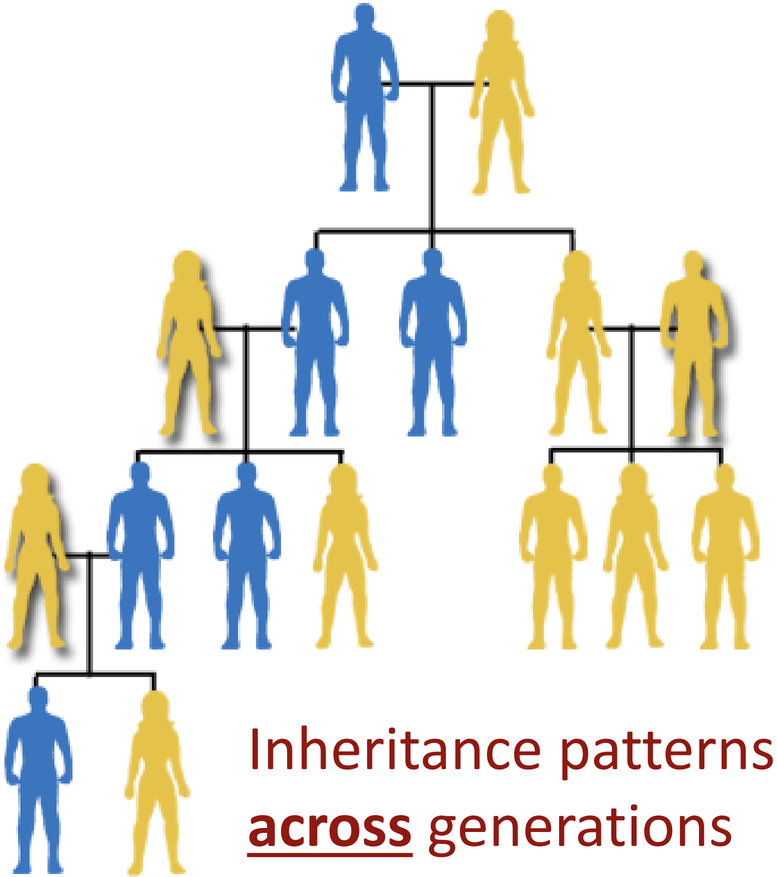
LS3: Heredity

"…focuses on the flow of genetic information between generations. This idea explains the mechanisms of genetic inheritance and describes the environmental and genetic causes of gene mutation and the alteration of gene expression."   [NRC Framework]

- **LS3A: Inheritance of traits**
- **LS3B: Variation of traits**

Three Models:

- Each chromosome pair contains two variants of each of many distinct genes.
- Relative dominance of the variants (alleles) within a a pair determines how the trait is expressed.

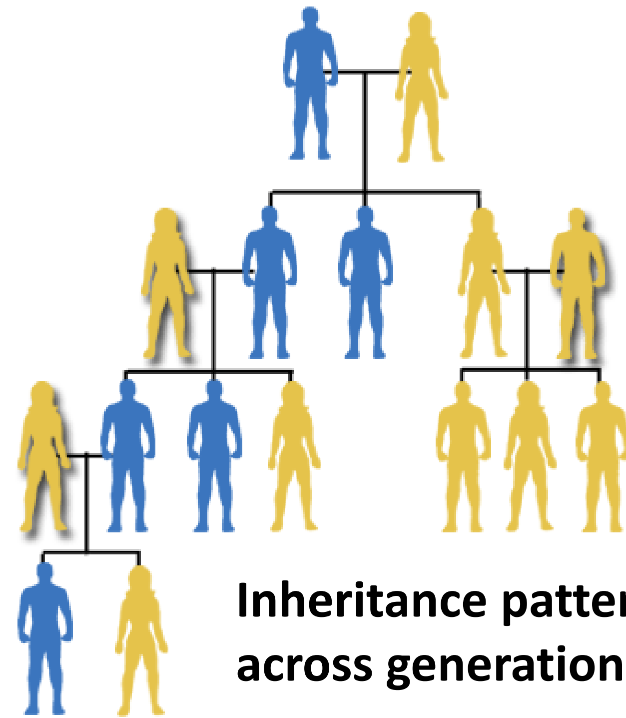


Inheritance patterns **<u>across</u>** generations

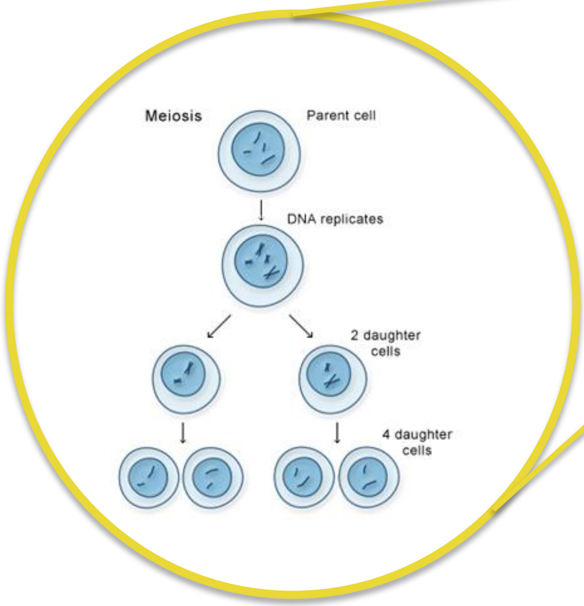
But, how do variants from the parents end up in the offspring?

Three Models:

- Offspring get half a chromosomal set from each parent.
- This allows for flow of genetic information from across generations



Inheritance patterns across generations

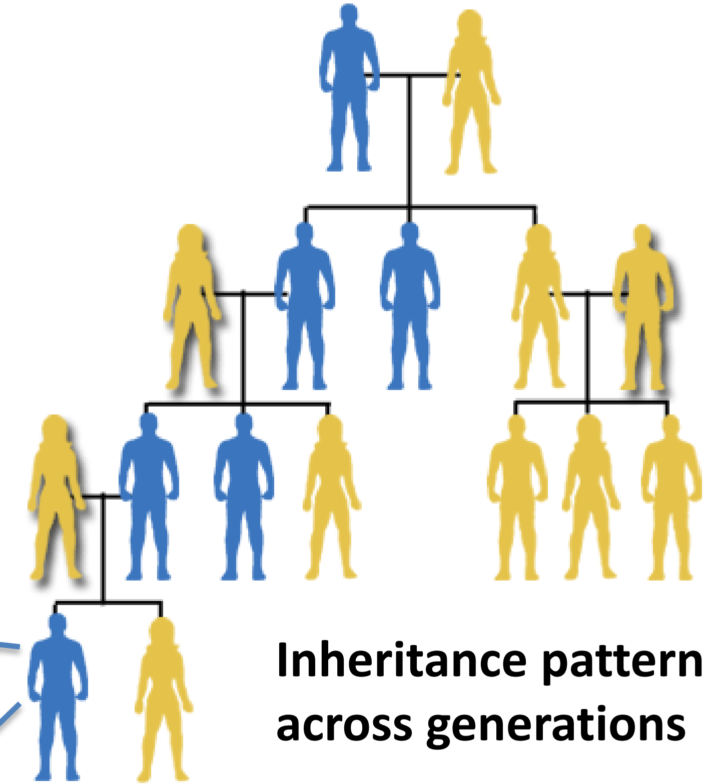


Flow of information from parent to offspring

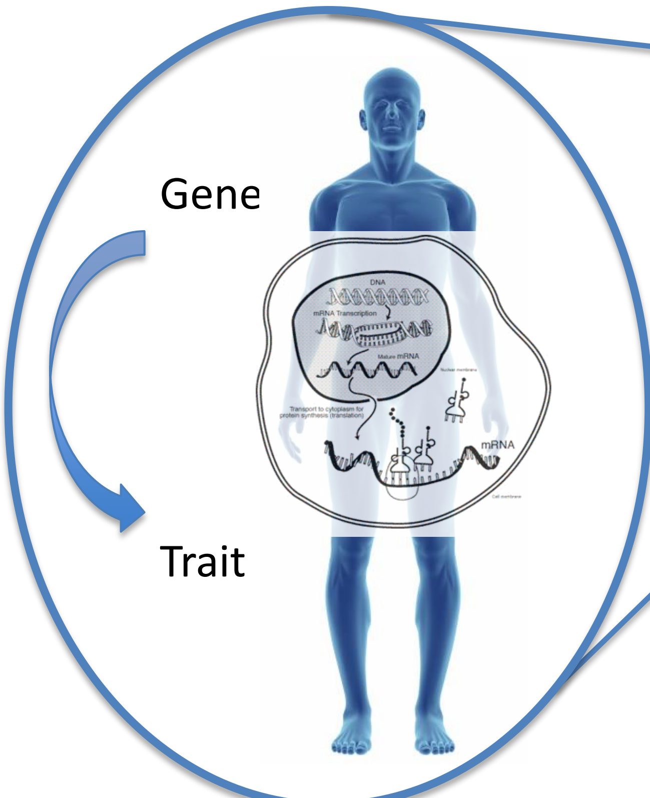
But once you get your variants, how do you end up with the trait?

Three Models:

"Genes encode the information for making specific <u>proteins</u>, which are responsible for the specific traits..."
NRC Framework



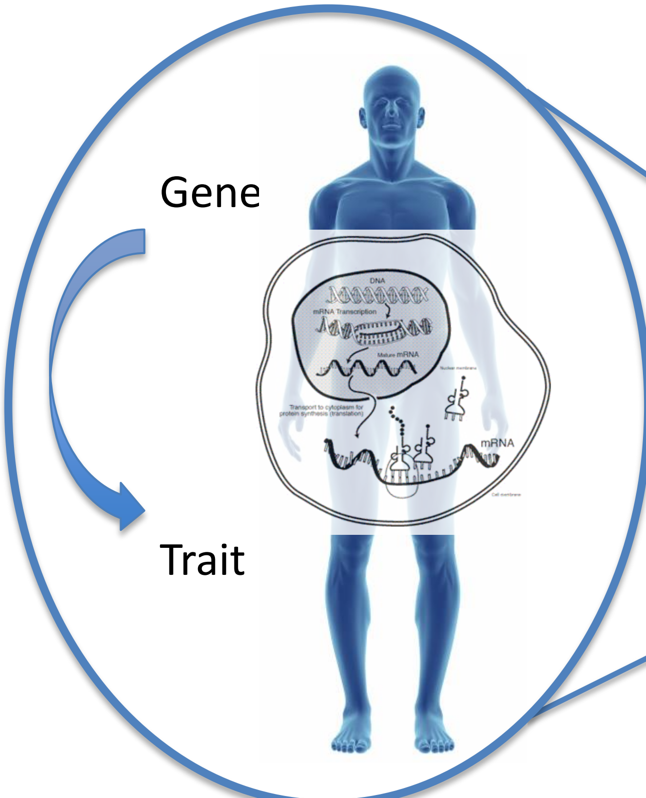
Inheritance patterns across generations

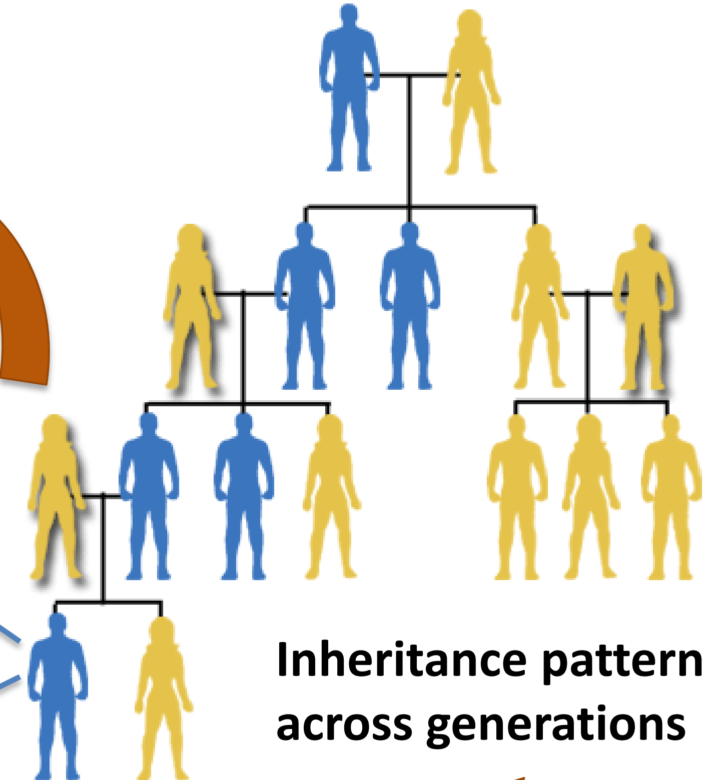


From information to physical trait: Mediating mechanisms

Three Models:

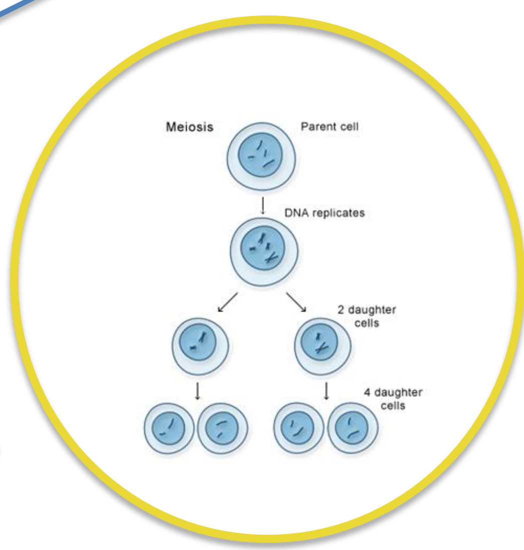
(Stewart, Cartier & Passmore, 2005)





Inheritance patterns across generations

From information to physical trait: Mediating mechanisms

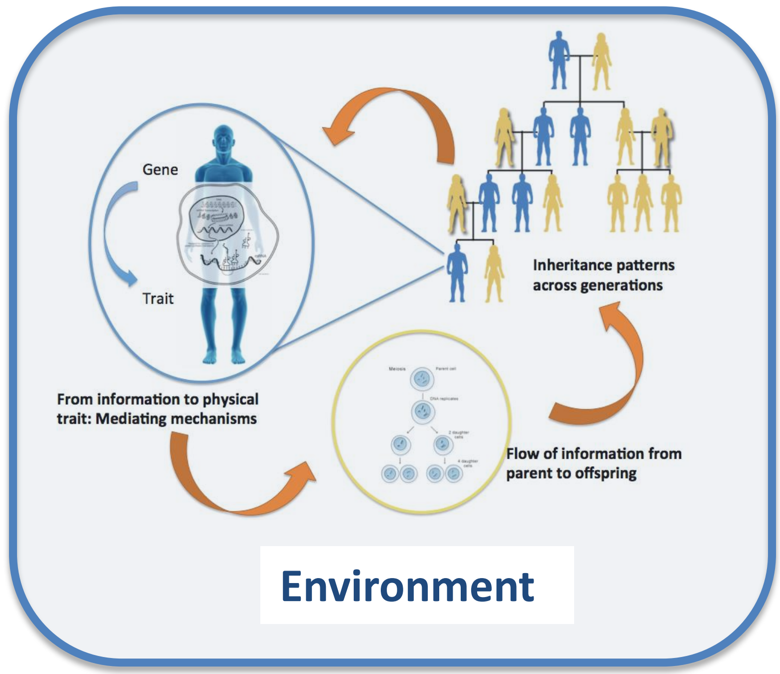


Flow of information from parent to offspring

The Role of the Environment

Two facets of the environment:

- The **genome** environment (complex interactions between genes)
- The **external** physical environment
  - The environment can alter genes- **mutations**
  - The environment can alter **gene expression**



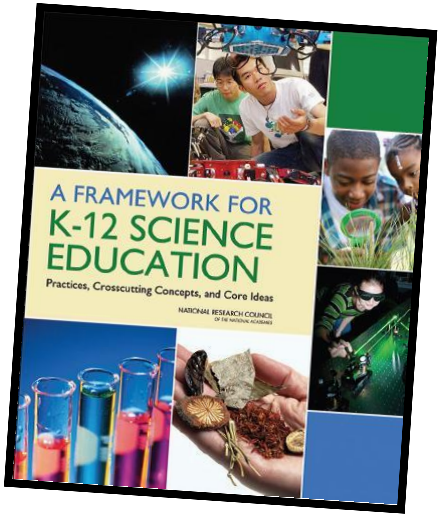
LS3: Summary

- Meiosis is presented in terms of input (2n) and output (n). Main idea here is "half a set"
- Sources of variation:
  - Sexual reproduction (segregation, independent assortment, and recombination)
  - Mutations
  - Interactions with environment
- Focus on mediating mechanisms - genes code for proteins, which are a key part of the story

Across generations

Within an individual

Questions?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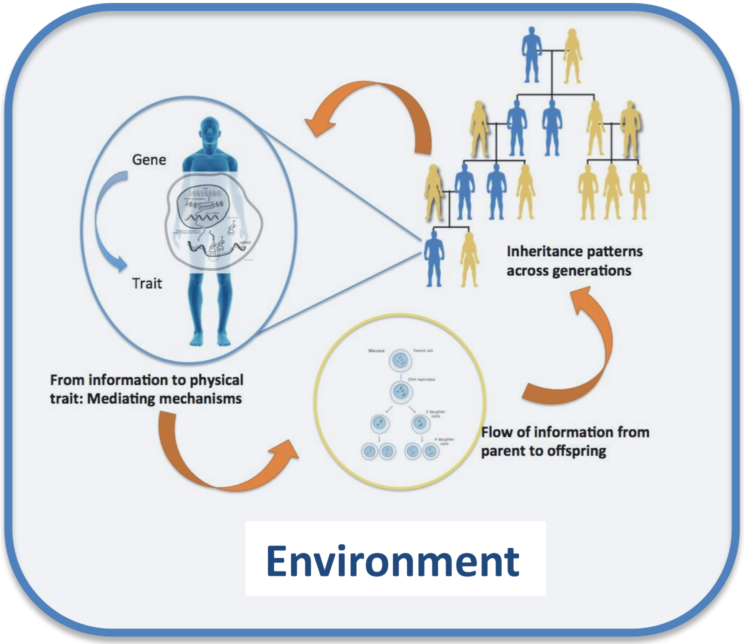
Practices, Crosscutting Concepts, and Core Ideas
NATIONAL RESEARCH COUNCIL


CAN TONY BLAIR STOP THE RUSH TO WAR?
Newsweek
THE INTERNATIONAL NEWSMAGAZINE
Frankenfood
The World Rebels Against America's Genetically Modified Crops


Gene
Trait
Inheritance patterns across generations
From information to physical trait: Mediating mechanisms
Flow of information from parent to offspring
Environment

Poll: When Should We Start?

We said that understanding the gene-protein connection is central to reasoning about genetic phenomena.

How early should we introduce this idea?

A. **Elementary school**; even such young students can reason about abstract ideas.

B. **Middle school**; students at this level are ready for thinking about unfamiliar and unseen entities.

C. **High school**; younger students do not have sufficient knowledge of chemistry and would struggle to reason about molecular structures.

Poll: When Should We Start?

We said that understanding the gene-protein connection is central to reasoning about genetic phenomena. How early should we introduce this idea?

B. Middle school; students at this level are ready for thinking about unfamiliar and unseen entities.

Framework's expectation for the end of 8th grade:

"Each gene chiefly controls the production of a specific protein, which in turn affects the traits of the individual…..Changes to genes (mutations) can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits".
[NRC Framework]

Learning Progression: Appendix E

High School

DNA carries the genetic information. Each cell in an organism has the same genetic information, but may express different genes.

Middle school

Genes chiefly regulate the production of a specific protein, which affects an individual's traits. Mutations to genes can alter proteins and subsequently the trait.

Late elementary

Organisms vary in how they look and function because they have different inherited information. The environment also affects traits that an organism develops.

Early Elementary

Young organisms are very similar, but not exactly the same as their parents and other members of their kind.

LS3A: Inheritance of Traits

Learning Progression: Appendix E

High School

Variation can arise from: sexual reproduction, including chromosomes swapping sections; mutations from environmental factors, or from errors in replication; and environmental impact on gene expression.

Middle school

Each chromosome pair has 2 variants (alleles) for each of many genes. Offspring receive one variant from each parent (half a set). Sexual reproduction and mutations drive variation in traits.

Late elementary

Organisms vary in how they look and function because they have different inherited information. The environment also affects traits that an organism develops.

Early Elementary

Young organisms are very similar, but not exactly the same as their parents and other members of their kind.

LS3B: Variation of Traits

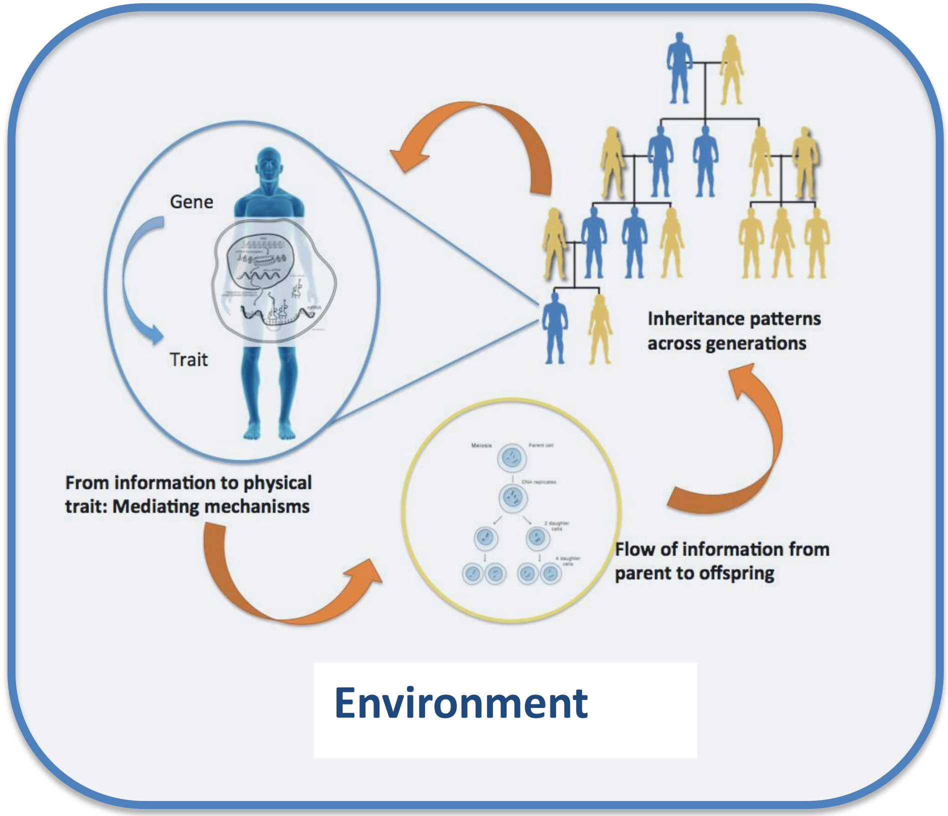
What is Progressing?

- **Macro - micro**: Movement from explanations at the macro level to ones that connect the macro to the micro
- **Deepening of causal mechanism**: from genes as information for traits -- to genes as productive instructions for proteins
- **Adding complexity and explanatory scope**: from variation due to random assortment -- to variation due to: (a) recombination, (b) mutation, and (c) environmental effects on gene expression

What is Progressing?

Connecting all three explanatory models:

- inheritance patterns,
- meiotic model,
- molecular model, and,
- the role of the environment



Building and deepening rather than repeating

Poll: Common Conceptual Obstacles

How do you think a typical <u>high school</u> student would answer this question:

Which of the following does DNA provide information for: (Choose most accurate answer)

A. The structure and function of a protein.

B. The traits that an individual inherits.

C. Assembling amino acids into protein molecules.

D. Assembling protein molecules into amino acids.

Poll: Common Conceptual Obstacles

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C. Assembling amino acids into protein molecules.

D. Assembling protein molecules into amino acids.

In a recent pilot with over 300 high school biology students:

Correct	Incorrect
23%	77%

Poll: Common Conceptual Obstacles

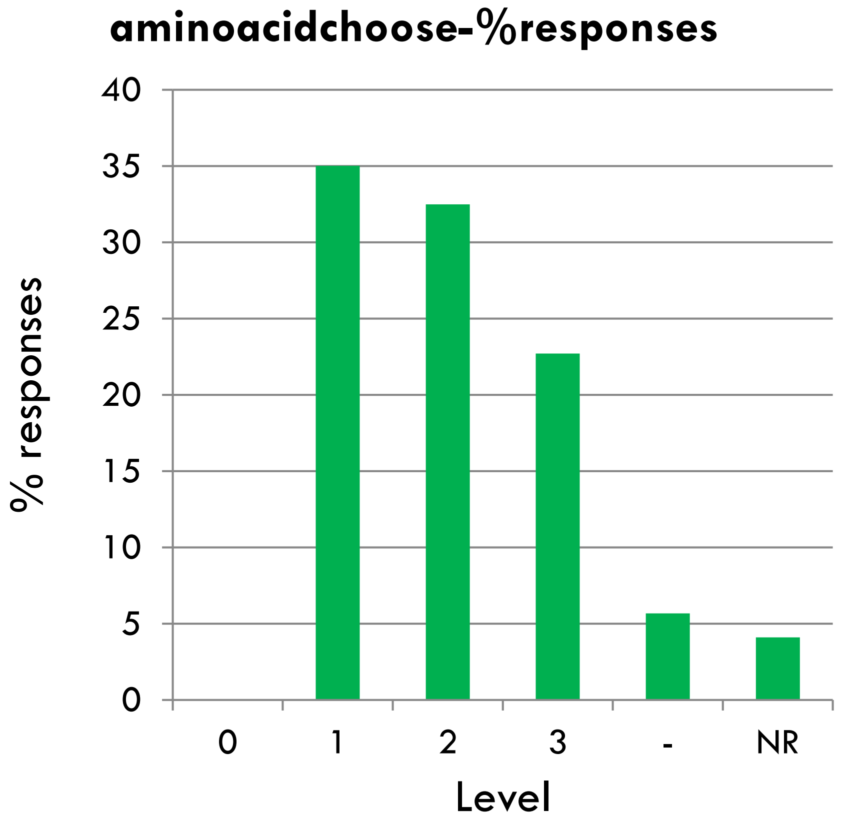
Which of the following does DNA provide information for: (Choose most accurate answer)

A. The structure and function of a protein. [L2]

B. The traits that an individual inherits. [L1]

C. Assembling amino acids into protein molecules. [L3]

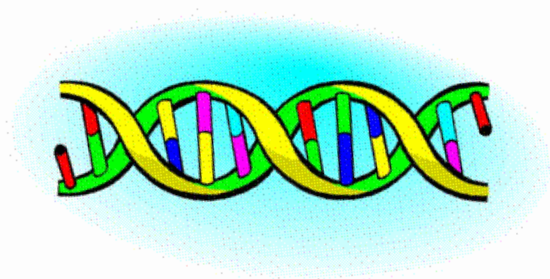
D. Assembling protein molecules into amino acids. [L-]

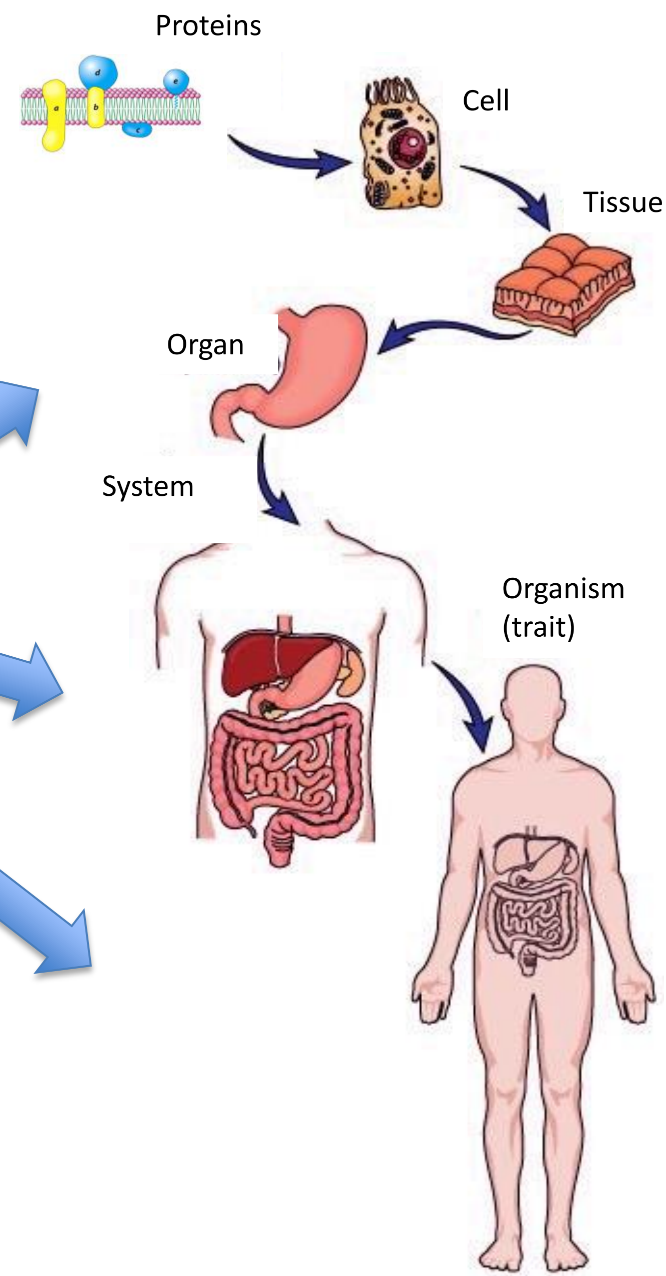


Correct	Incorrect
23%	77%

Nature of the Genetic Information

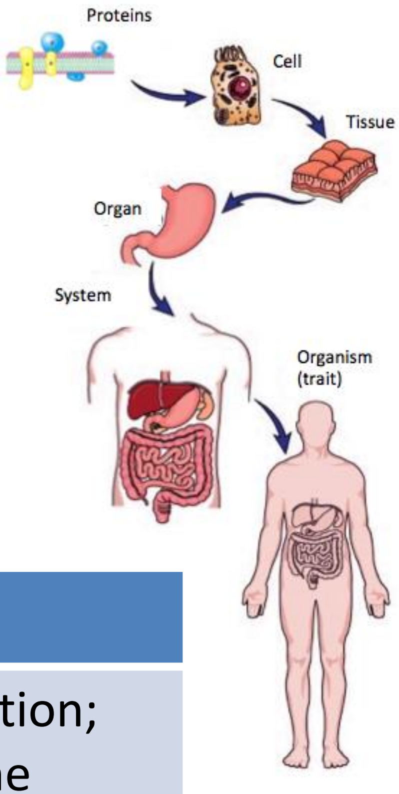
Many biological organization levels…





Where does the genetic information come in?

Nature of the Genetic Information



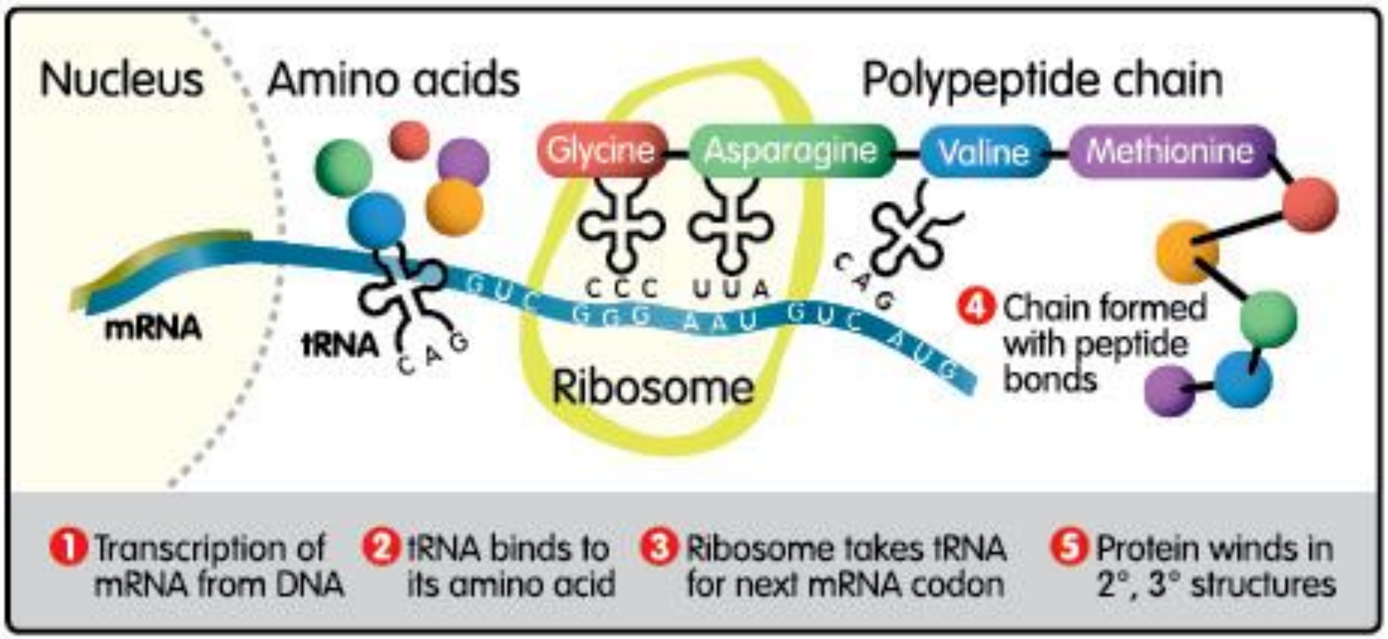
Trajectory of conceptual change for the concept of gene: (Venville & Treagust, 1998)

Concept	Example
Genes as passive particles associated with traits	No sense of genetic information; genes and traits are the same
Genes as instructions	Genes have information for everything about you (all levels)
Genes as productive instructions for proteins	Genes have instructions for making proteins (only protein level)

Corollary: To truly understand the gene-trait connection you need to understand proteins and their biological role.

Proteins: The Missing Level

We explain the central dogma in relative detail…



But then drop the ball in terms of explaining what the resulting protein does.

Poll: The Role of Proteins

How do you think a typical <u>high school</u> student would answer the following item:

Janice and Bill are arguing about what proteins do in our bodies.

Janice says that proteins are important for making your hair, muscles, nails, and that they are also enzymes.

Bill agrees with Janice. But he also thinks that proteins do a lot more than what Janice said. They are also hormones, antibodies, and they can even give signals to cells.

Who is correct?

A. Janice is correct.   B. Bill is correct.

C. Janice is mostly correct, except that she left out that proteins give us energy.

D. Bill is mostly correct, except that proteins do not give signals to cells.

Role of Proteins

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Bill agrees with Janice. But he also thinks that proteins do a lot more than what Janice said. They are also hormones, antibodies, and they can even give signals to cells.

Who is correct?

A. Janice is correct. [L1]

B. Bill is correct. [L3]

C. Janice is mostly correct, except that she left out that proteins give us energy. [L0]

D. Bill is mostly correct, except that proteins do not give signals to cells. [L2]

If we look at how many students got it right:

Correct	Incorrect
34%	66%

Role of Proteins

Janice and Bill are arguing about what proteins do in our bodies.

Janice says that proteins are important for making your hair, muscles, nails, and that they are also enzymes.

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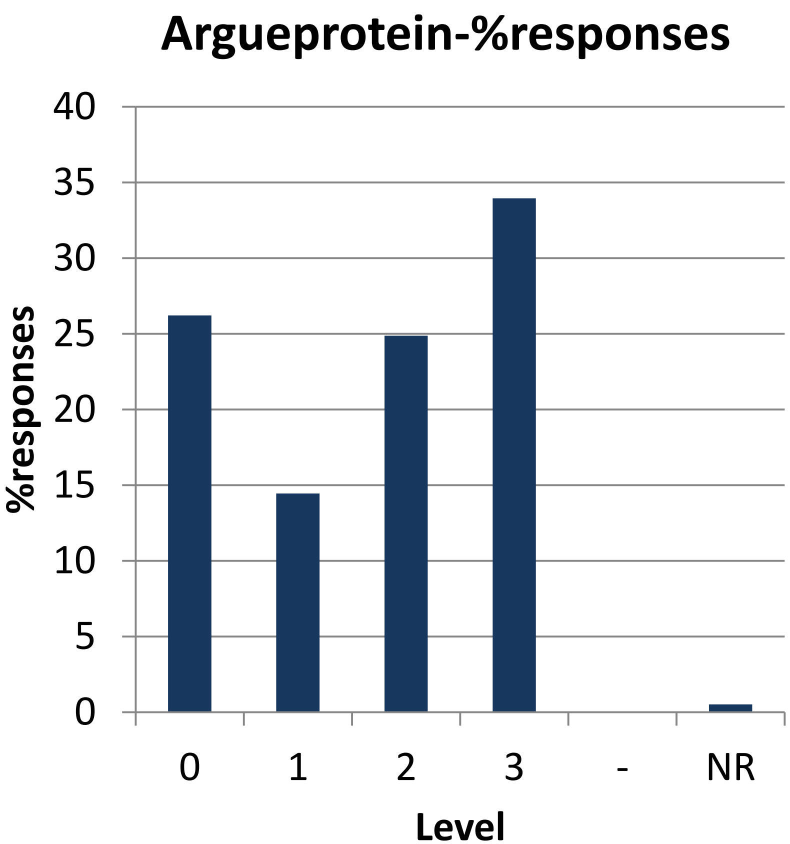


Correct	Incorrect
34%	66%

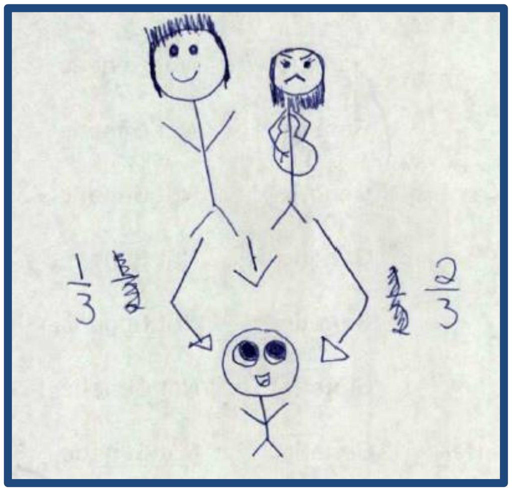
A Few Key Points

- Viewing genes as productive instructions for proteins is a big conceptual jump
- It is important to build up students' conceptual toolkit of protein functions
- Less focus on details, more focus on domain-appropriate reasoning - **a generalized schema:**

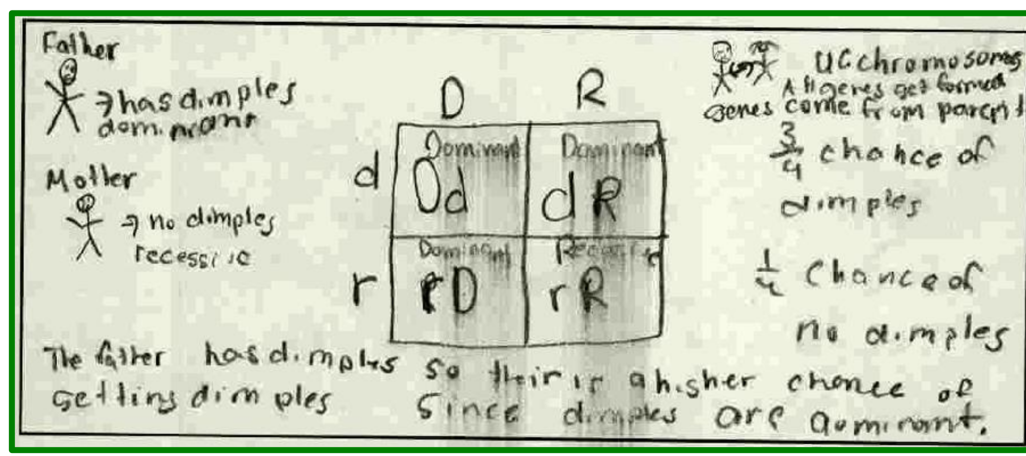
Gene → Protein Function → Trait

Mutation in Gene → Non-functional Protein → Altered Trait

Conceptual Obstacles for Classical Genetics



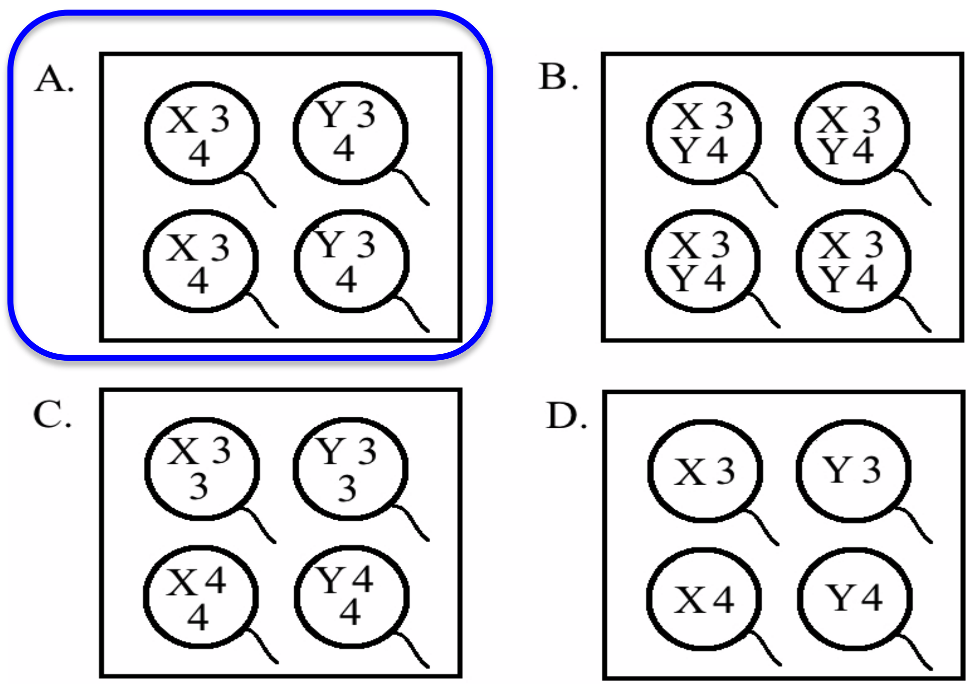
- Students begin with a theory of kinship – offspring look like their parents - that is non-mechanistic. (Springer & Kiel, 1989)
- They do not always assume equal contribution by parents. (Engel, Clough & Wood-Robinson, 1985)
- The idea of 2 alleles is not obvious.
- They may be able to use terms and representations but often they do not have a firm grasp of the underlying concept. (Stewart, 1982; Lewis & Wood-Robinson, 2000)



Conceptual Hurdles for Classical Genetics

How do you think a typical high school student would answer the following item:

A human male has the following chromosome pairs in his body cells: [**X,Y**; **3, 3**; **4, 4**] which chromosome combinations will be in his sperm cells?



Conceptual Hurdles for Classical Genetics

How do you think a typical high school student would answer the following item:

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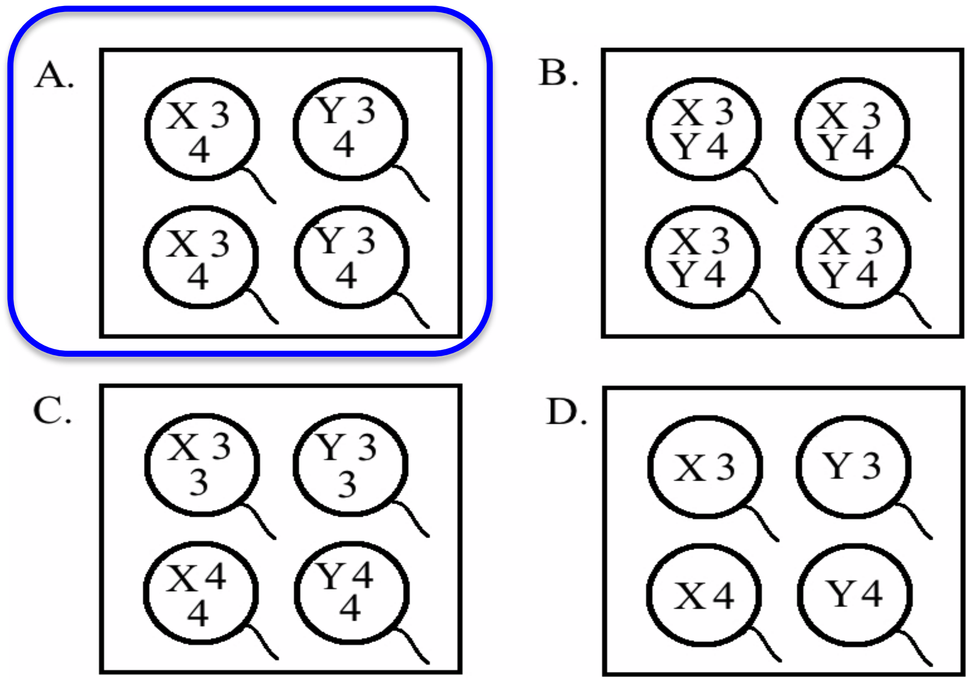
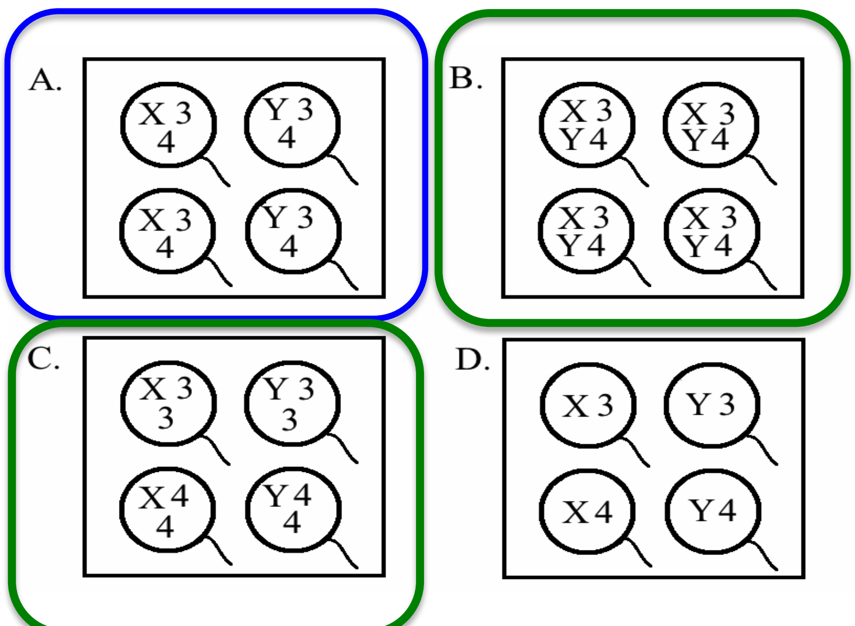
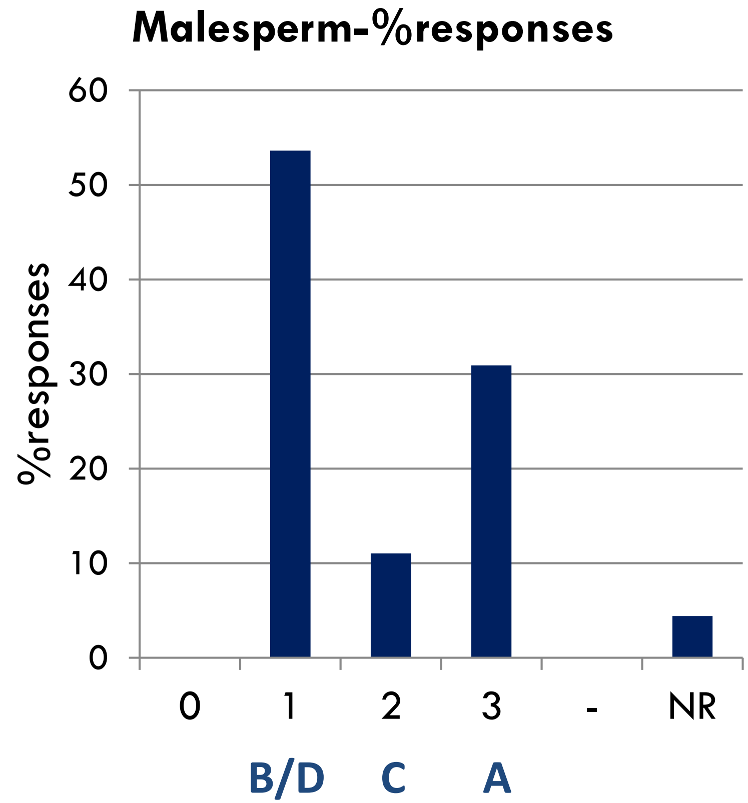


Correct	Incorrect
31%	69%

Conceptual Hurdles for Classical Genetics

A human male has the following chromosome pairs in his body cells: [X,Y; 3, 3; 4, 4] which chromosome combinations will be in his sperm cells?



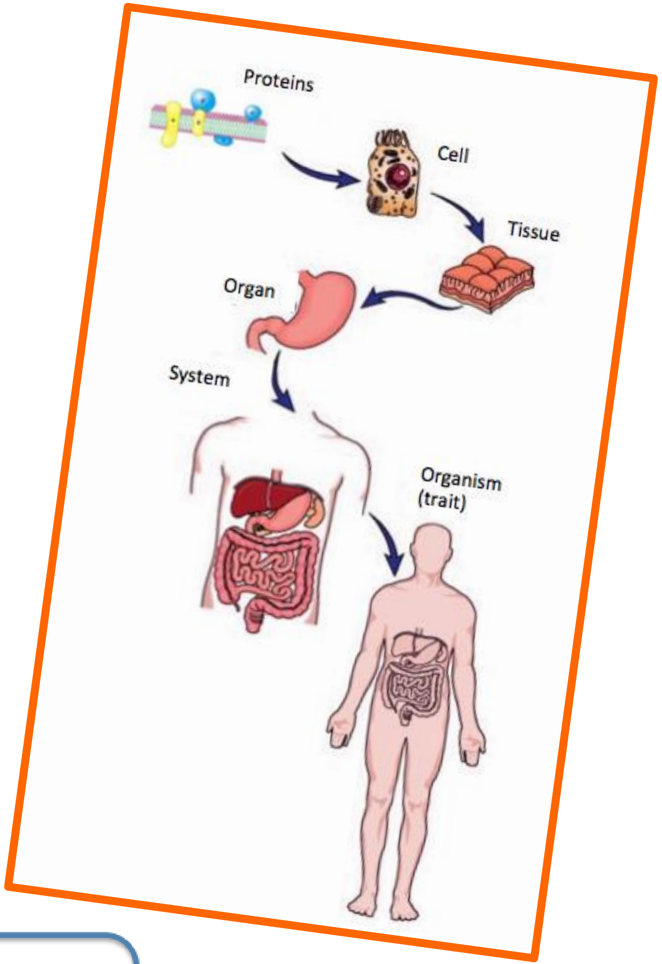


Students don't always understand "half" as "half a set"

A Few Key Points

- **Focusing on the details of processes like meiosis does not necessarily lead to understanding the big idea**
  - Similarly, students may be able to use genetic representations without fully understanding them
- **Build ideas first and label them with terms later**
  - Push for mechanism
- **We need to help students integrate the many terms and ideas in genetics into a coherent model**
  - There is robust confusion about the the relationship between DNA, chromosomes, alleles, and genes

Questions?



Gene → Protein Function → Trait

Mutation in Gene → Non-functional Protein → Altered Trait

Shifts in the Standards: NSES versus NGSS

- Earlier and more extensive focus on the mechanisms that link genes to traits (proteins)
- Greater stress on variation and its sources
- Emphasis on the interplay between genes and the environment
  - Mutations
  - Gene expression

Teaching Strategies and Resources

A key aspect of NGSS is the integration of **inquiry practices:**

Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. **Middle School**

Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms. **3rd Grade**

Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents. **1st Grade**

Teaching Strategies and Resources

Young students can identify similarities and differences between offspring and parents (humans, animals, and plants). They can identify inherited versus non-inherited variations.

Make observations to construct an evidence-based account
that young plants and animals are like, but not exactly like, their parents. **1st Grade**

Teaching Strategies and Resources

Students can use fast plants to generate evidence about variation and heritability of traits:

- Make observations (color)
- Measure (height)
- Compare offspring to parents and to non-parent plants
- Chart variations in a population and in "families"

Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms. **3rd Grade**

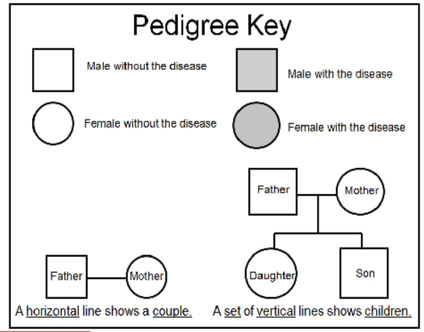
Modeling in Genetics

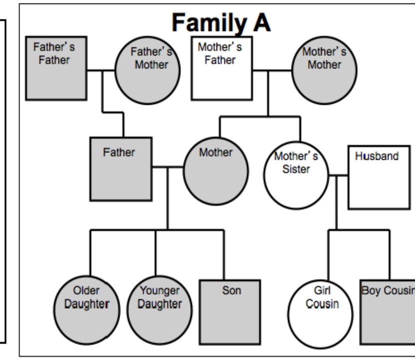
Older students can use evidence, such as pedigrees, to develop a model of how traits are inherited

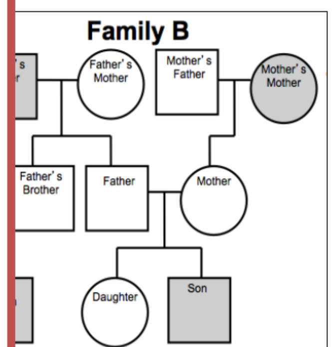
Genetics Lesson 3 Evidence 3 v3 Student ID: ____

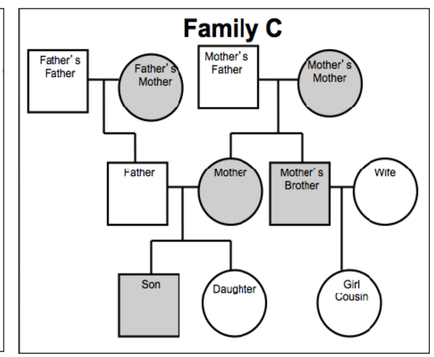
Evidence 3

Below are three different pedigrees. Each pedigree shows a family of a mother, father, three children and their grandparents. For each person in each family write down what gene or genes you think they have. Write these in the squares and circles. You can work on this evidence in groups (2 pairs per group).









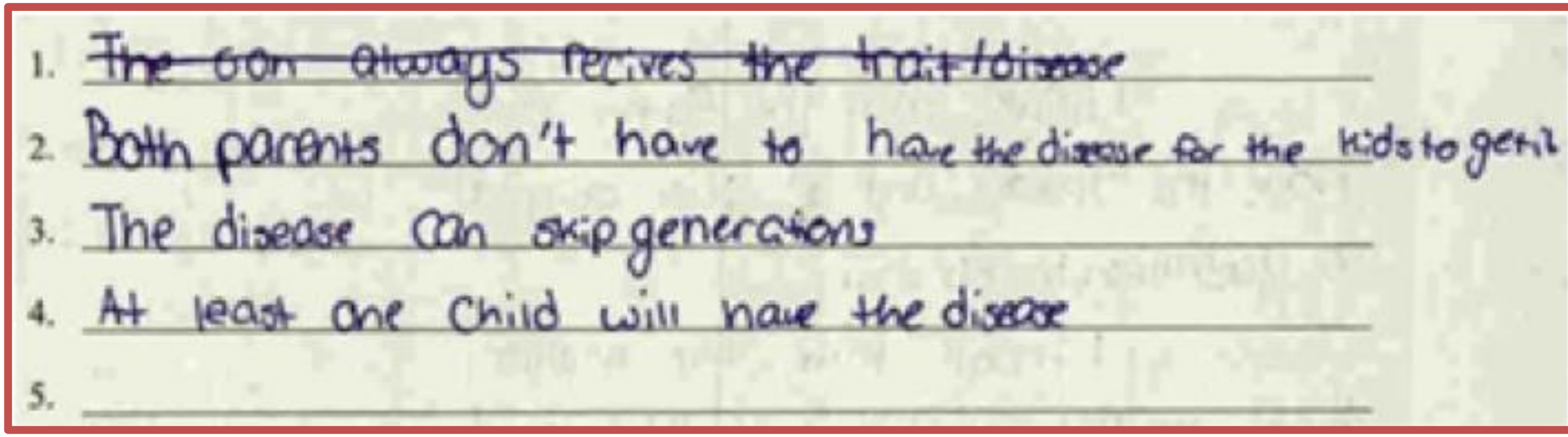
Evidence 1: Human Traits – Sara

Some New Jersey high school students were interested in understanding how people inherit their traits. To find out they first randomly chose a person in their class (Sara) and recorded her traits. They then observed Sara's parents and recorded their traits. Here are their findings:

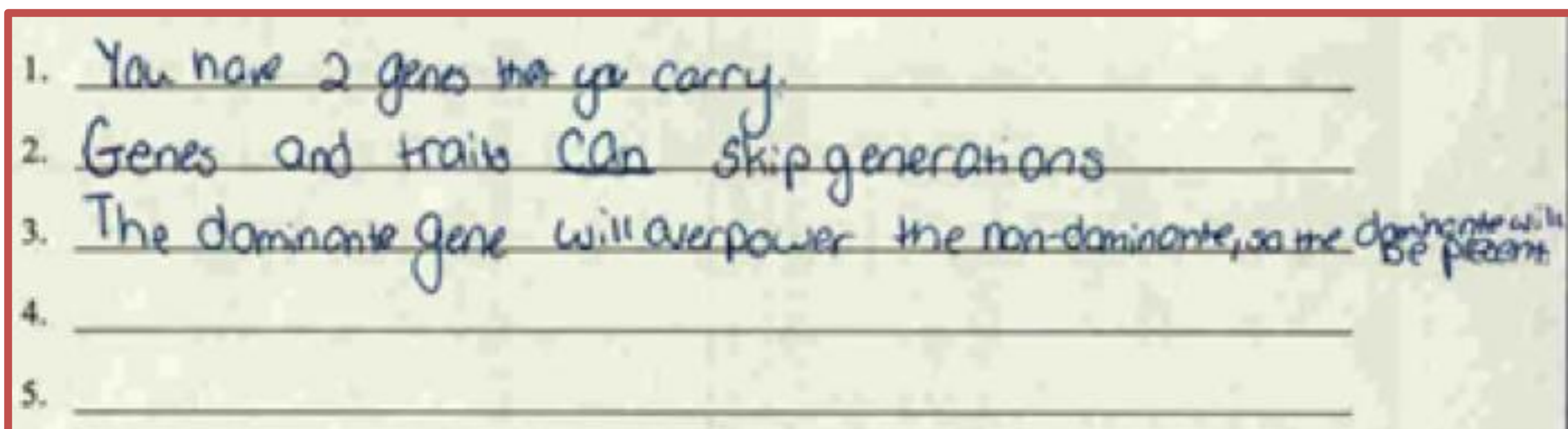
Sara	Sara's Father	Sara's Mother
Dimples	Dimples	No Dimples
Unattached Earlobes	Unattached Earlobes	Attached Earlobes
Widow's Peak	Widow's Peak	Straight Hairline
Straight Thumb	Straight Thumb	Straight Thumb
Can Roll Tongue	Can't Roll Tongue	Can Roll Tongue
Can Taste PTC	Can Taste PTC	Can't Taste PTC

Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. **Middle School**

Modeling in Genetics


1. ~~The son always recives the trait/disease~~
2. Both parents don't have to have the disease for the kids to get it
3. The disease can skip generations
4. At least one child will have the disease
5.

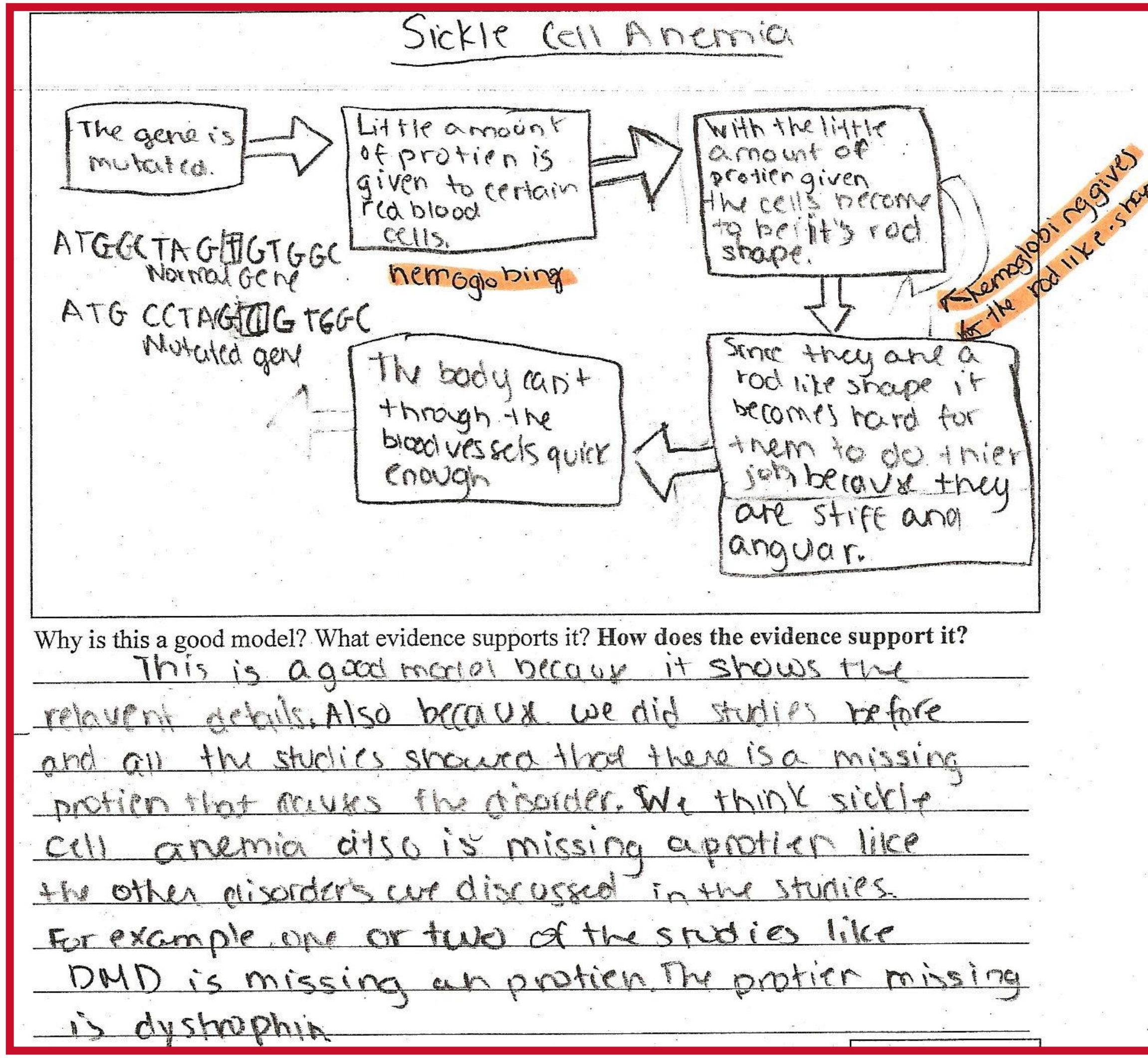
Students develop and revise their “rule model” based on new evidence provided:


1. You have 2 genes that you carry.
2. Genes and traits can skip generations
3. The dominante gene will overpower the non-dominante, so the dominante will be present
4.
5.

Modeling in Genetics

This can also be done for molecular genetics:

- Students can develop a model for the biological basis of a genetic disorder

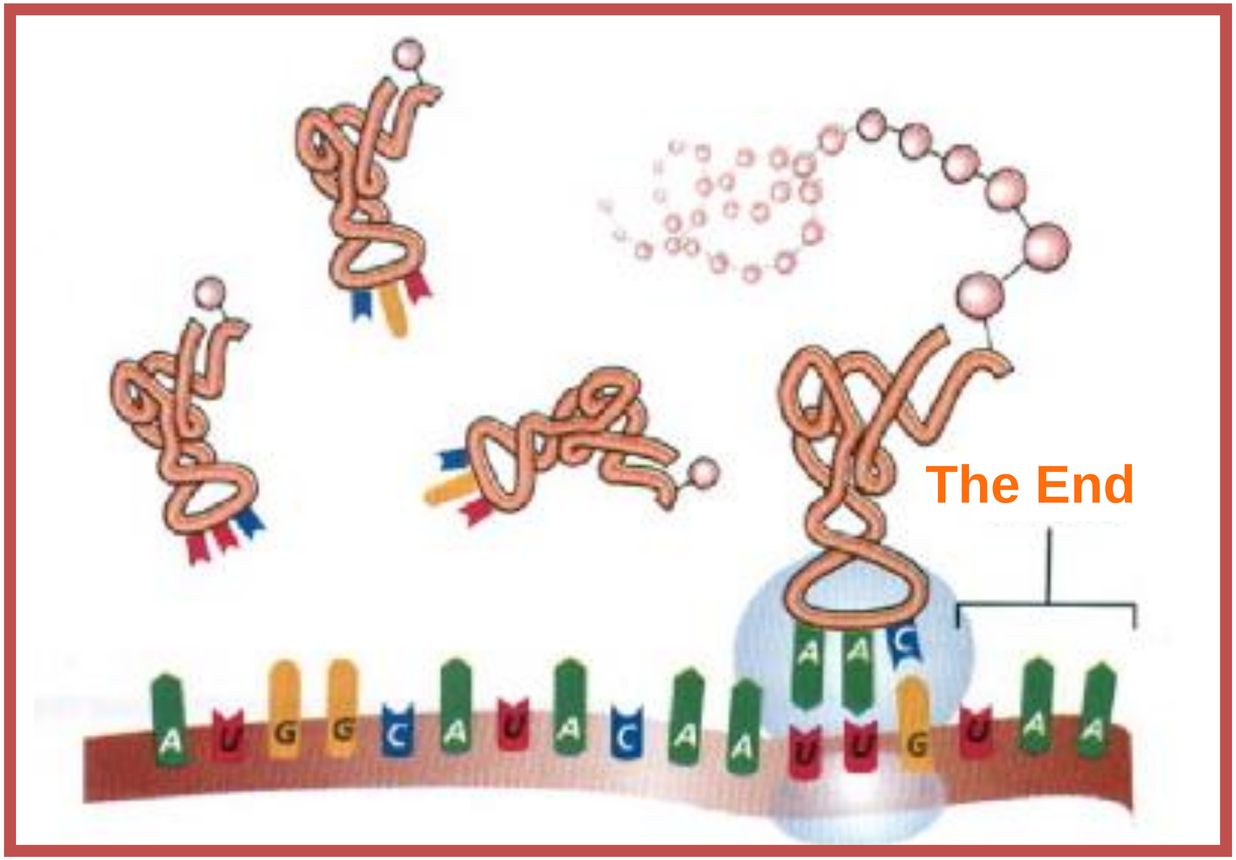


Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. **Middle School**

Other Resources

- **Concord Consortium**
  http://concord.org/
  - Molecular Workbench
  - Geniverse
- **AAAS Project 2061** science assessment
  - Assessment items and information about student performance on them: http://assessment.aaas.org/topics/RH#
- **WISE**
  http://wise.berkeley.edu/
  - Heredity modules for late elementary
  - Includes FastPlants as a learning tool

Thank You!



I would also like to acknowledge the contribution of

Nicole Shea

to this presentation

ravit.duncan@gse.rutgers.edu

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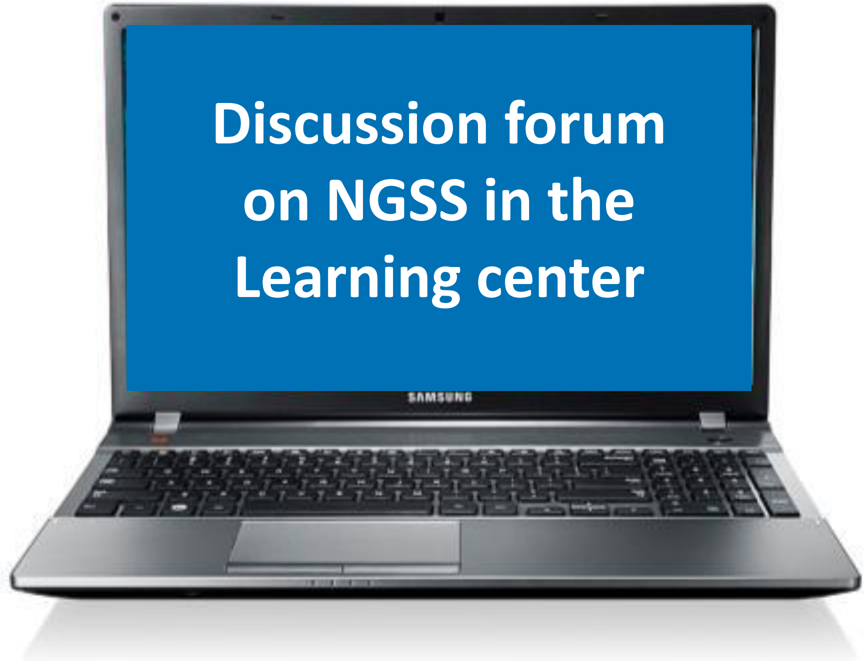

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February 11: Interactions, Energy, and Dynamics

February 25: Heredity: Inheritance and Variation of Traits

March 11: Biological Evolution: Unity and Diversity

Coming in March/April: Engineering design and nature of science

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- Disciplinary Core Ideas (Fall 2013, Spring 2014)
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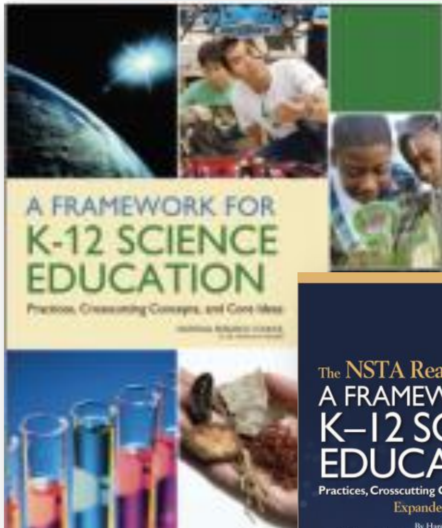
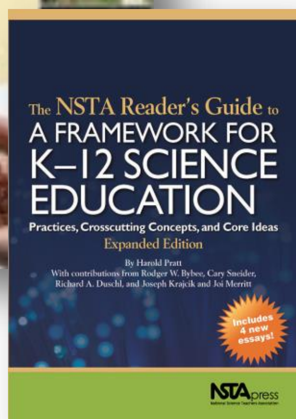
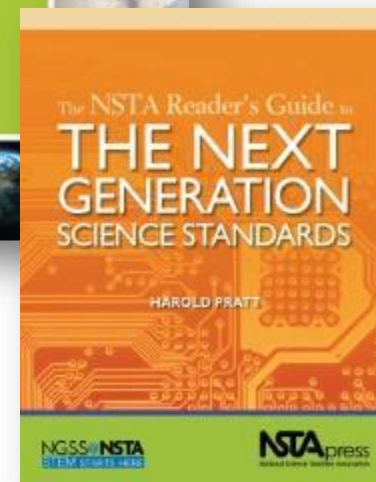
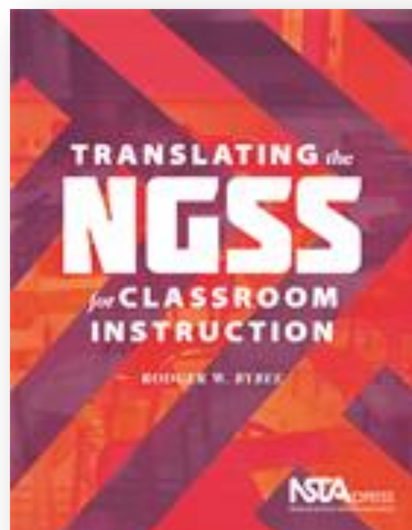
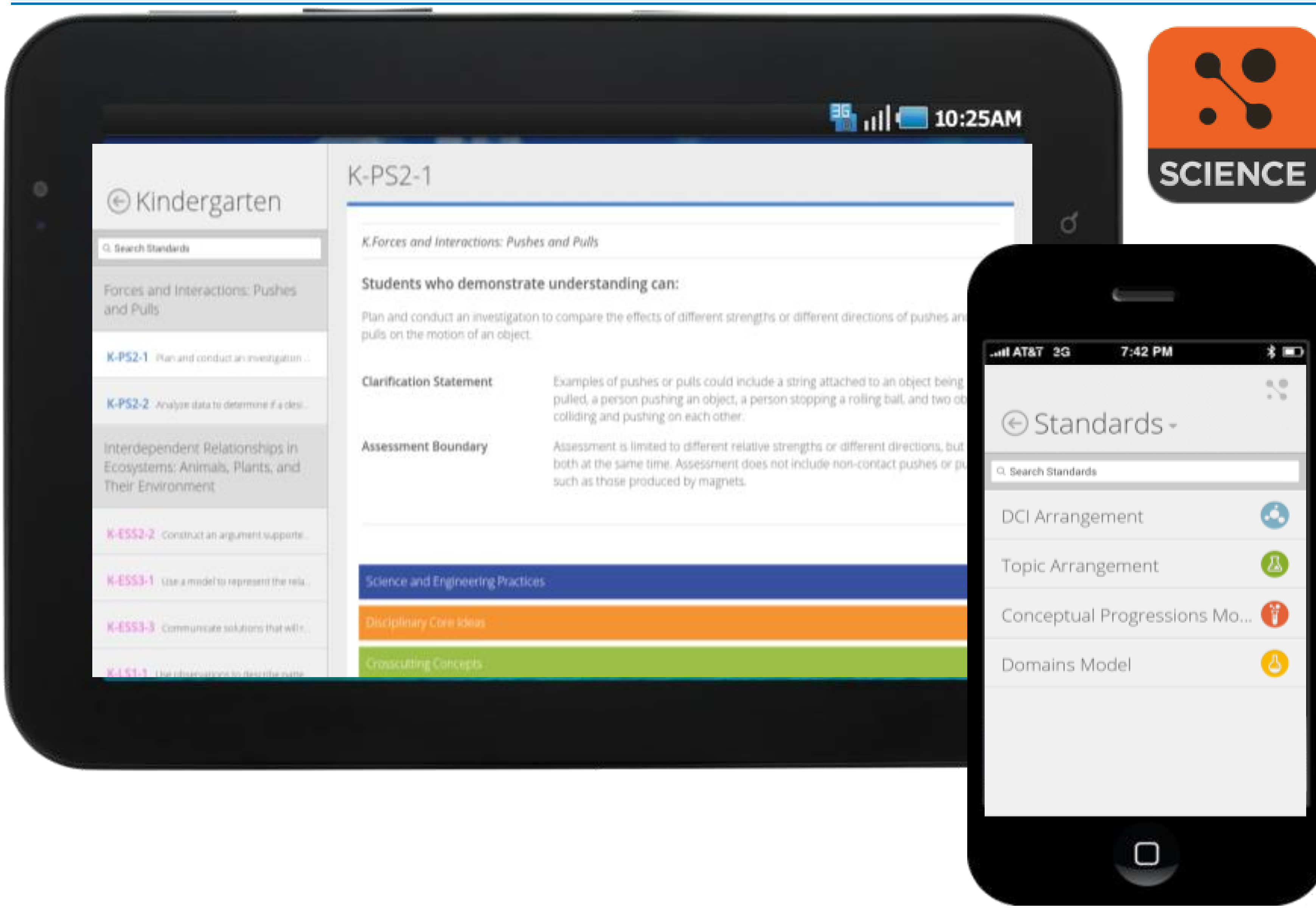








NGSS App



10:25AM
Kindergarten
Search Standards
Forces and Interactions: Pushes and Pulls
K-PS2-1 Plan and conduct an investigation ...
K-PS2-2 Analyze data to determine if a desi...
Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment
K-ESS2-2 Construct an argument supporte...
K-ESS3-1 Use a model to represent the rela...
K-ESS3-3 Communicate solutions that will r...
K-PS2-1
K.Forces and Interactions: Pushes and Pulls
Students who demonstrate understanding can:
Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes an
pulls on the motion of an object.
Clarification Statement
Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two ob
colliding and pushing on each other.
Assessment Boundary
Assessment is limited to different relative strengths or different directions, but
both at the same time. Assessment does not include non-contact pushes or pu
such as those produced by magnets.
Science and Engineering Practices
Disciplinary Core Ideas
Crosscutting Concepts
AT&T 3G
7:42 PM
Standards
Search Standards
DCI Arrangement
Topic Arrangement
Conceptual Progressions Mo...
Domains Model

Future Conferences

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Boston – April 3-6, 2014

Thanks to today's presenters!

Ted Willard
Director, NGSS@NSTA
National Science Teachers Association

Ravit Golan Duncan
Associate Professor of Science Education
Rutgers University

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