Quantifying systems thinking skills: Using modified Data Nuggets

Joelyn de Lima

Biology is the study of systems!

- What is systems thinking?
- What are systems thinking skills?
- What do models have to do with systems thinking skills?
- How can we use this in instruction and assessment?

- Using a modified Data Nugget!

- Middle and High School
  - HS-LS1-2, HS-LS1-4, HS-LS1-5, HS-LS1-7, HS-LS1-2, HS-LS1-4, HS-LS2-2, HS-LS2-6, HS-LS4-1


Union City
MANHATTAN
New York
Hamilton Park
Weehawken
HELL'S KITCHEN
MIDTOWN
SUTTON PLACE
UPPER EAST SIDE
UPPER WEST SIDE
CARNEGIE HILL
LENOX HILL
HUNTERS POINT
LONG ISLAND CITY
GREENPOINT
WILLIAMSBURG
EAST WILLIAMSBURG
VINEGAR HILL
LOWER MANHATTAN
EAST VILLAGE
Times Square
Rockefeller Center
Empire State Building
The High Line
Central Park Zoo
Carnegie Hall
Trump Tower
Lincoln Center for the Performing Arts
Washington Square Park
Brooklyn Bridge
Manhattan Bridge
Brooklyn Navy Yard
Battery Park
Brooklyn Bridge Park
Tenement Museum
McCarren Park
Williamsburg Bridge
Google


Union City
MANHATTAN
New York
Live traffic

Systems

Ben-Zvi Assaraf & Orion, 2005; Penner, 2000; Wilensky & Resnick, 1999

Systems

- A collection of parts and/or processes
- More than just a sum of their parts

Ben-Zvi Assaraf & Orion, 2005; Penner, 2000; Wilensky & Resnick, 1999

Systems Thinking

- "The art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure" (Richmond, 1994)
- Analysing parts and synthesising the information into a whole
- Set of related skills

Ben-Zvi Assaraf & Orion, 2005; Hmelo, Holton, & Kolodner, 2000

Why Systems Thinking Skills?

Biology is the study of systems!

Ben-Zvi Assaraf & Orion, 2005; Hmelo, Holton, & Kolodner, 2000

Biology is the study of systems!

Why Systems Thinking Skills?

- Enable the efficient analysis and synthesis of information to gain a comprehensive understanding of complex phenomena.

- Understand intricacies of systems
  - generate better predictions
  - adjust their outcomes

Ben-Zvi Assaraf & Orion, 2005; Hmelo, Holton, & Kolodner, 2000

Systems Thinking in Education

- 5 skills that needs to be a focus of education in the 21st century

The National Academies of | SCIENCES ENGINEERING MEDICINE

- Systems - Core concept

- Systems and System Models - Crosscutting concept

NEXT GENERATION SCIENCE STANDARDS

The state of the research

Systems thinking education:

- human organ systems
- multicellularity
- water cycle

Ben-Zvi Assaraf & Orion, 2005; Hmelo, Holton, & Kolodner, 2000; Lin & Hu, 2003; Monat, 2018; Penner, 2000; Raved & Yarden, 2014

Problems

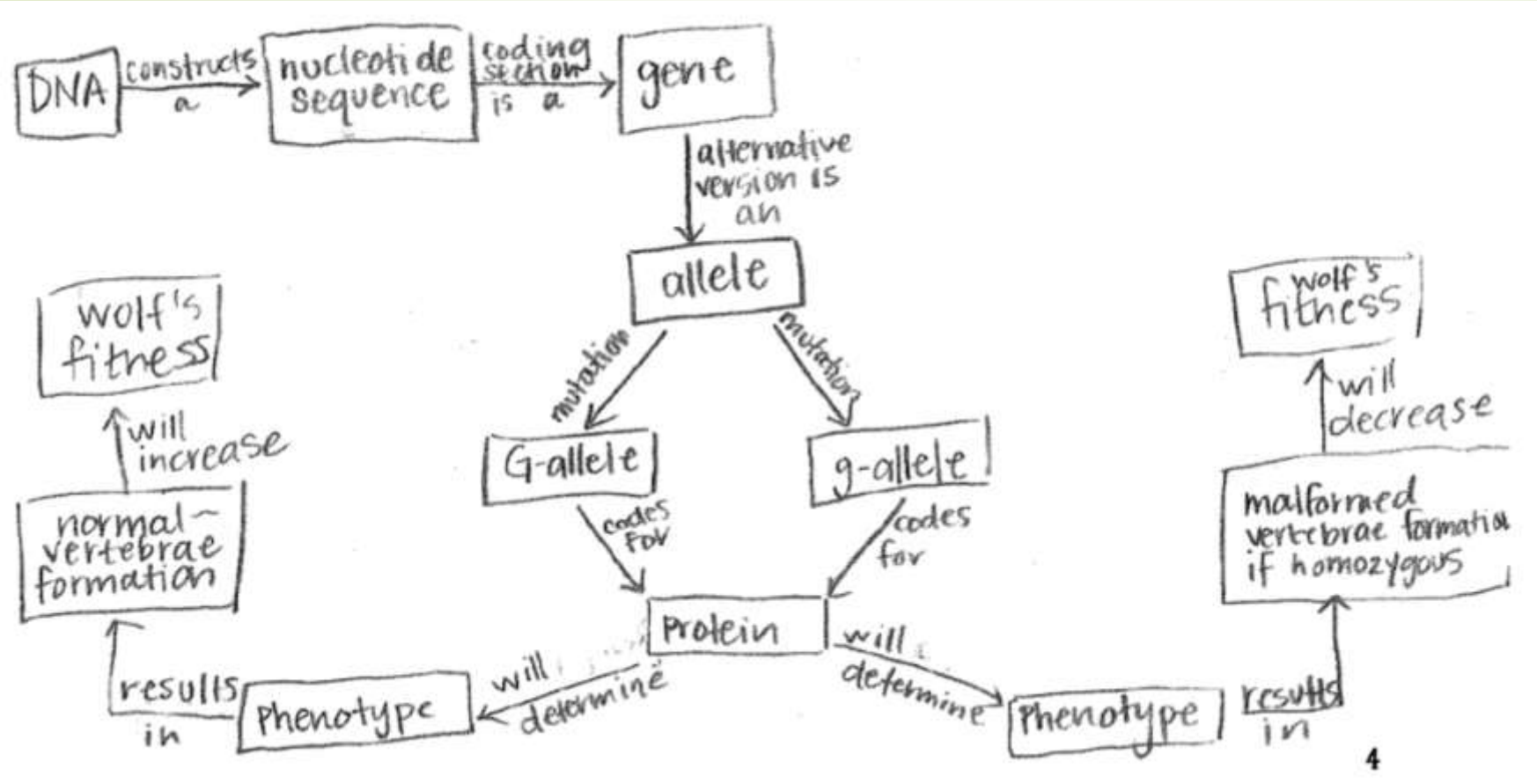
- Students:
  - have little understanding about even relatively simple systems.
  - find it difficult to analyse the parts and processes of a system and synthesise them into a coherent whole

Ben-Zvi Assaraf & Orion, 2005; Hmelo, Holton, & Kolodner, 2000; Lin & Hu, 2003; Monat, 2018; Penner, 2000; Raved & Yarden, 2014

Quantifying systems thinking

1. The ability to **identify the components** of a system and **processes** within the system
2. The ability to **identify relationships** among the system's components
3. The ability to **organise** the systems' components and processes within a **framework** of relationships
4. The ability to **make generalisations**
5. The ability to **identify dynamic relationships** within the system
6. Understanding the **hidden dimensions** of the system
7. The ability to **understand the cyclic nature** of systems
8. **Thinking temporally**: retrospection and prediction

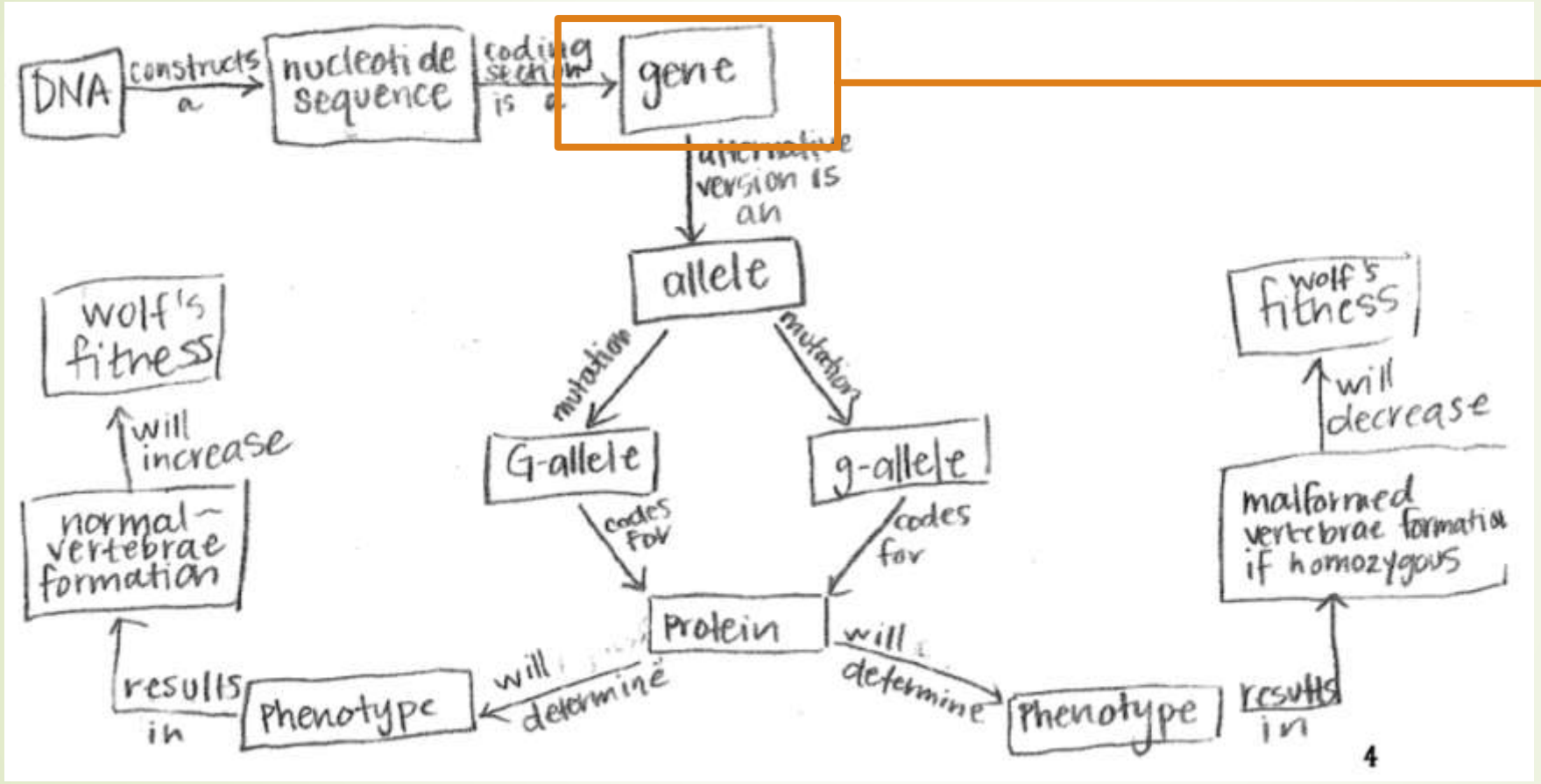
Ben-Zvi Assaraf & Orion, 2005


DNA
constructs a
nucleotide sequence
coding section is a
gene
alternative version is an
allele
mutation
mutation
G-allele
g-allele
codes for
codes for
Protein
will determine
will determine
Phenotype
Phenotype
results in
results in
malformed vertebrae formation if homozygous
will decrease
wolf's fitness
normal vertebrae formation
will increase
wolf's fitness
4

Quantifying systems thinking

1. The ability to **identify the components** of a system and **processes** within the system
2. The ability to **identify relationships** among the system's components
3. The ability to **organise** the systems' components and processes within a **framework** of relationships
4. The ability to **make generalisations**
5. The ability to **identify dynamic relationships** within the system
6. Understanding the **hidden dimensions** of the system
7. The ability to **understand the cyclic nature** of systems
8. **Thinking temporally**: retrospection and prediction

Ben-Zvi Assaraf & Orion, 2005

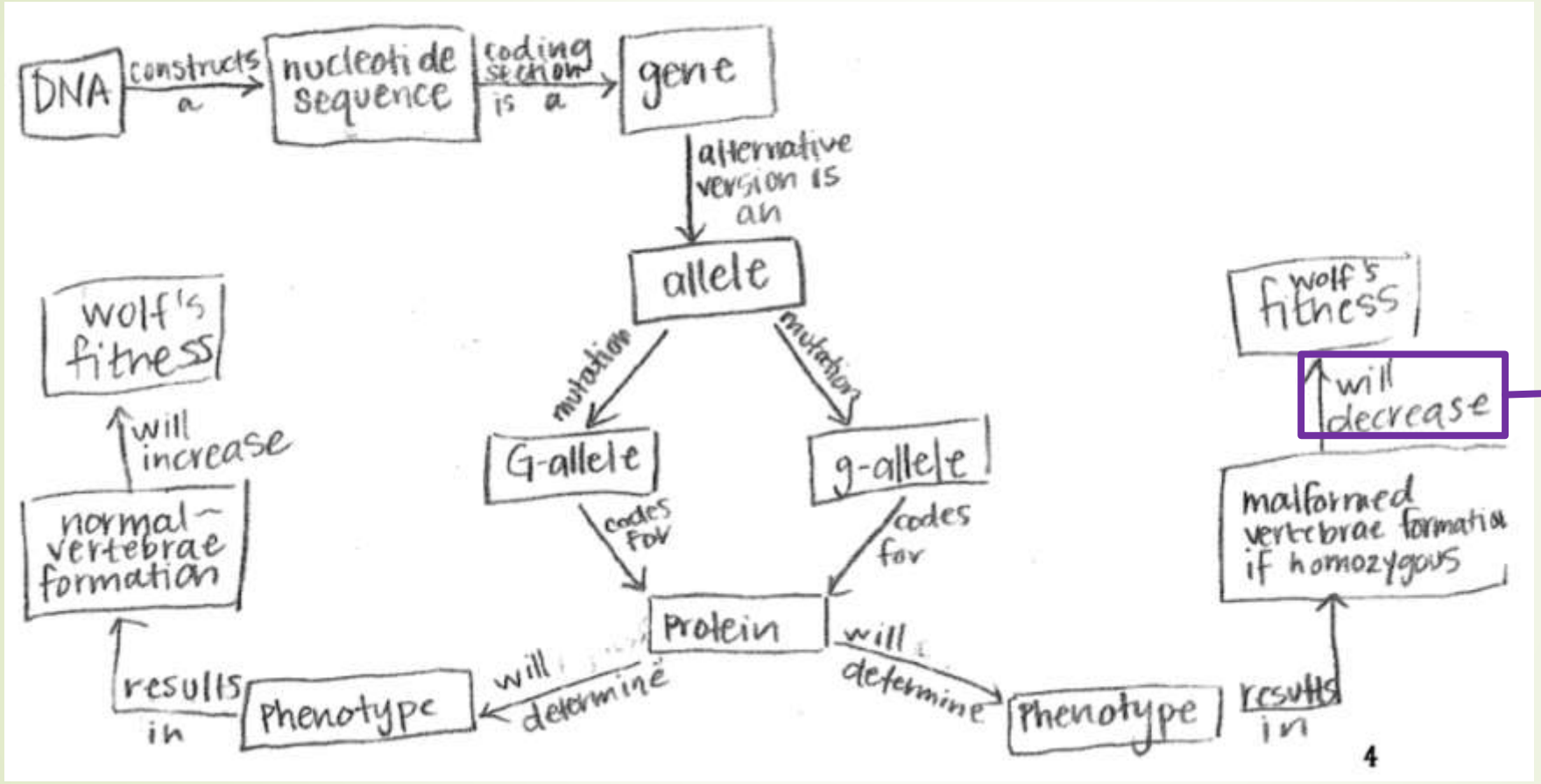

DNA
constructs a
nucleotide sequence
coding section is a
gene
alternative version is an
allele
mutation
mutation
G-allele
g-allele
codes for
codes for
protein
will determine
will determine
phenotype
phenotype
results in
results in
wolf's fitness
will increase
normal vertebrae formation
wolf's fitness
will decrease
malformed vertebrae formation if homozygous
4

Components

Quantifying systems thinking

1. The ability to **identify the components** of a system and **processes** within the system
2. The ability to **identify relationships** among the system's components
3. The ability to **organise** the systems' components and processes within a **framework** of relationships
4. The ability to **make generalisations**
5. The ability to **identify dynamic relationships** within the system
6. Understanding the **hidden dimensions** of the system
7. The ability to **understand the cyclic nature** of systems
8. **Thinking temporally**: retrospection and prediction

Ben-Zvi Assaraf & Orion, 2005

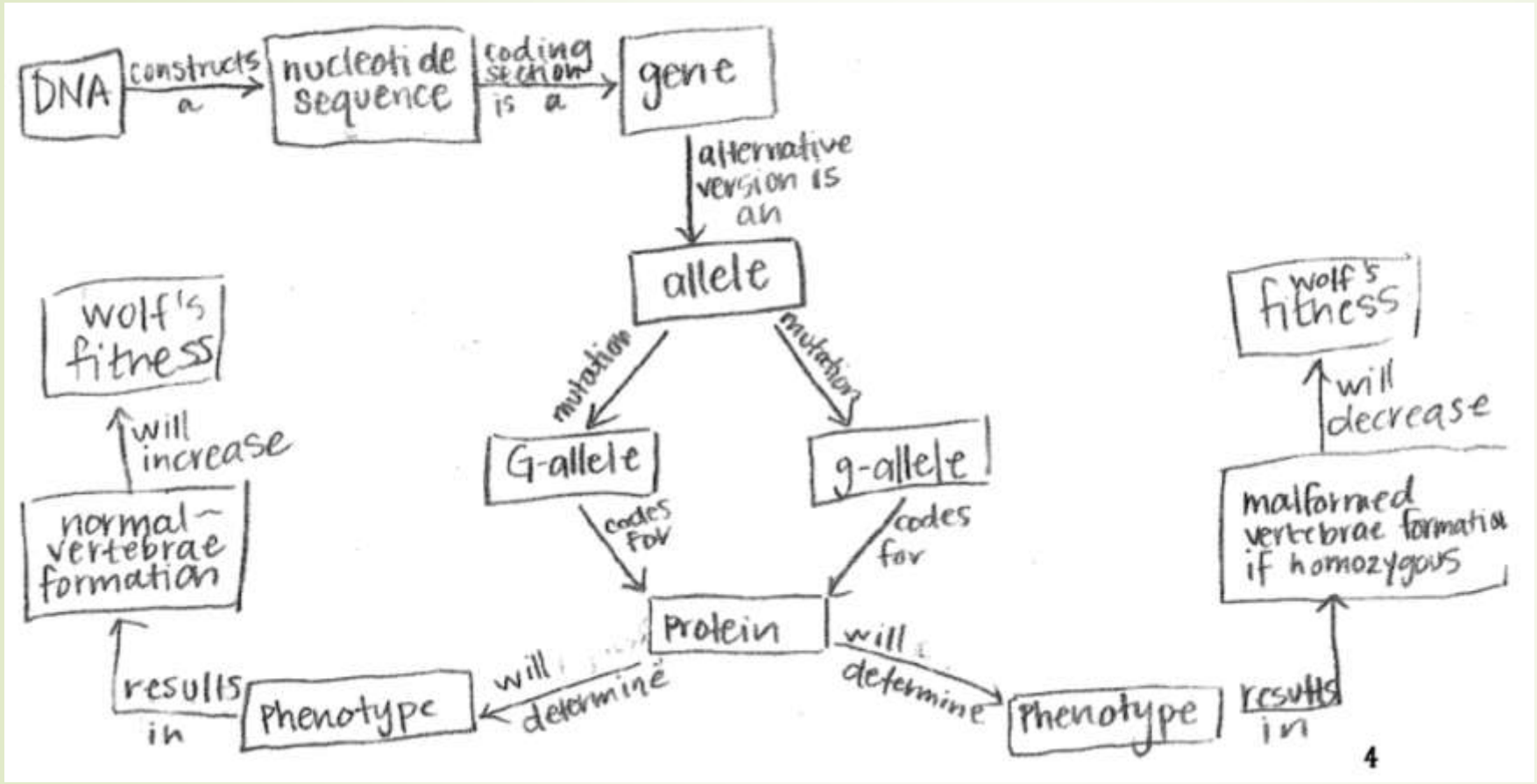


Relationships

Quantifying systems thinking

1. The ability to **identify the components** of a system and **processes** within the system
2. The ability to **identify relationships** among the system's components
3. The ability to **organise** the systems' components and processes within a **framework** of relationships
4. The ability to **make generalisations**
5. The ability to **identify dynamic relationships** within the system
6. Understanding the **hidden dimensions** of the system
7. The ability to **understand the cyclic nature** of systems
8. **Thinking temporally**: retrospection and prediction

Ben-Zvi Assaraf & Orion, 2005


DNA
constructs a
nucleotide sequence
coding section is a
gene
alternative version is an
allele
mutation
mutation
G-allele
g-allele
codes for
codes for
Protein
will determine
will determine
Phenotype
Phenotype
results in
results in
malformed vertebrae formation if homozygous
will decrease
wolf's fitness
normal vertebrae formation
will increase
wolf's fitness
4

Complexity

Data Nuggets

DATA Nugget **How a Hawaiian Cricket Lost its Song**
Based on work by Dr. Robin Tinghitella, University of Denver

Background: Some of the most vibrant and elaborate traits in the animal kingdom are signals used to attract mates. These mating signals include the bright feathers of birds and the loud calls of male frogs. More often than not, it is the males who display the mating signal, and the females who use those signals to choose a mate. About 30 years of research has focused on how mating signals become so elaborate and why females have such strong preferences for the signals. Even Darwin recognized that the advantage of a bird's bright feathers could not have been survival - the same signals used to attract mates also attract predators!

Model Organism: Dr. Tinghitella studies the mating signals of Pacific field crickets, *Teleogryllus oceanicus*. These crickets live on several Hawaiian Islands, including Kauai. Male field crickets make a loud, long-distance song to help females find them, and then switch to a quiet courtship song once a female comes in close. Males use specialized structures on the wings, called the file and scraper, to produce songs (Figure 1).

Case Study: One summer, early on in graduate school, Robin noticed that the crickets on the island of Kauai were unusually quiet. No males were singing, and only a couple of years before, Kauai had been a very loud place to work. After taking the crickets back to the lab, she noticed that there was something different about the males' wings on Kauai. Almost all the males (95%) were missing all of the wing structures that are used to produce the calling and courtship songs – they had completely lost the ability to produce song! She decided to call this new type of male a flatwing male.

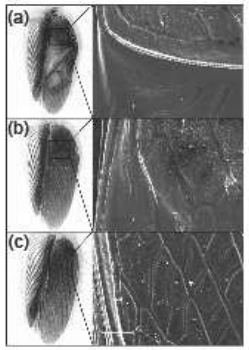


Figure 1. (a) Male wing with normal calling structures. (b) Male wing with the flatwing mutation. (c) Female wing.

On Kauai, male cricket songs not only attract female crickets, but also a deadly parasitoid fly called *Ormia ochracea* (Figure 2). The fly's larvae are sprayed on the cricket's backs, burrow into the crickets' body cavity, and literally eat them from the inside out! Before the flatwing mutation, more than 30% of males on Kauai were parasitized. Robin collected 122 males on the island of Kauai, and dissected them to look for fly larvae (Table 1).

Figure 2. The fly sitting on top of its cricket host.

	Male Crickets	
	With normal wings	With Flatwings
Parasitized	25	1
Not Parasitized	42	121
% Parasitized	37.31	0.82

Table 1. Counts and percentages of parasitism in the male cricket population of Kauai.

Data Nuggets developed by Michigan State University fellows in the NSF BEACON and GK-12 programs

1

- Instructional resources
- Designed to promote the quantitative reasoning and data analysis skills
- Real researchers and real science!
- Developed by MSU graduate students

Schultheis, E. H., & Kjelvik, M. K. (2015).

Let's model some systems!

Identifying the components of a system

- Count!
- What's in there?

Slide with unpublished research data

Slide with unpublished research data

Identifying relationships

- Count!
- What's in there?

Slide with unpublished research data

Slide with unpublished research data

Organising within a framework

- Web causality index (WCI)

- Proportion of structures with >1 ‘in’ arrow
- Proportion of structures with >1 ‘out’ arrow
- Sum of the above

- Range 0 - 2

Slide with unpublished research data

Slide with unpublished research data

Questions?