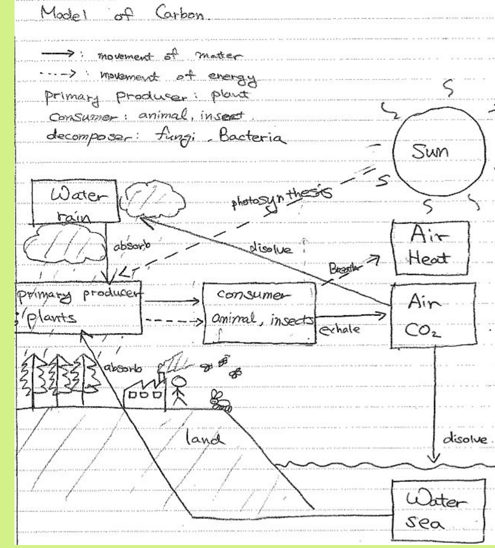
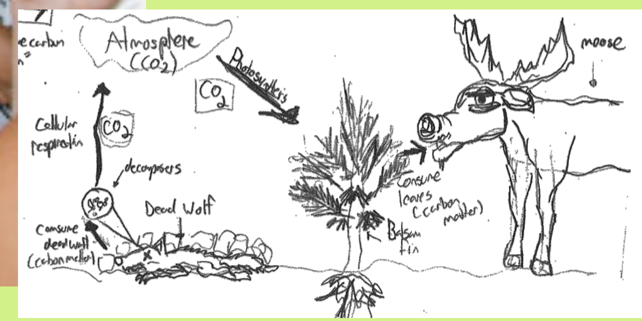




Beyond Concept Maps: System models as a tool for simplifying complexity in undergraduate biology.

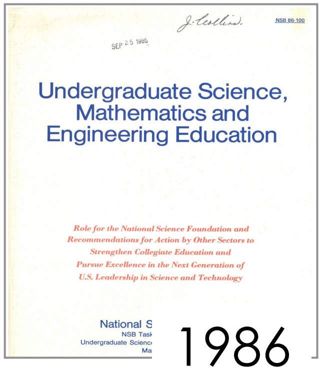
Tammy M. Long (longta@msu.edu)

Discovering Life, Doing Science, Minneapolis, MN, March 16, 2013.

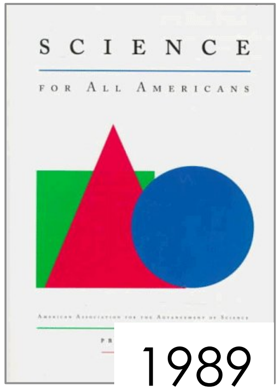
Required tools:

Objectives:

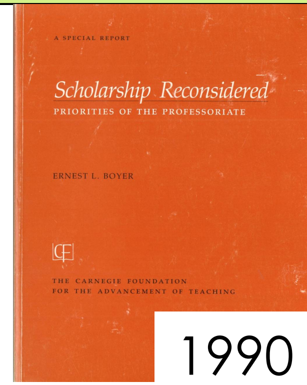
- Context for development
- Defining a "system model"
- Learning value of models
- Applications in classroom



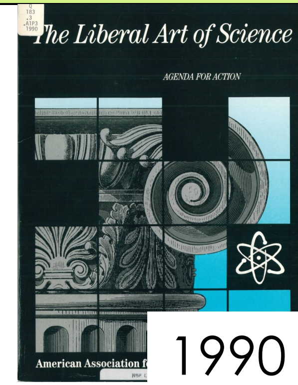
1986



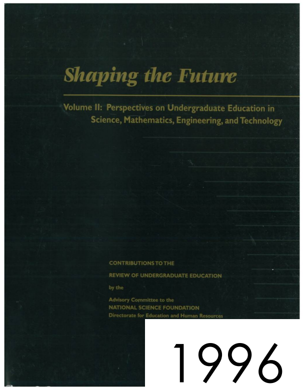
1989



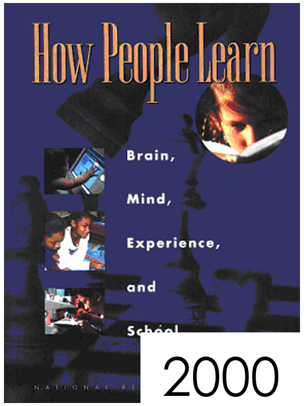
1990



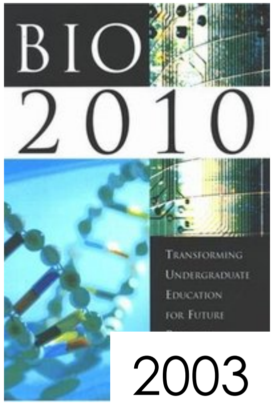
1990



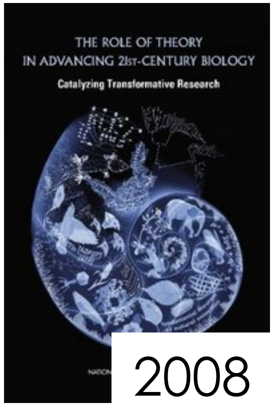
1996



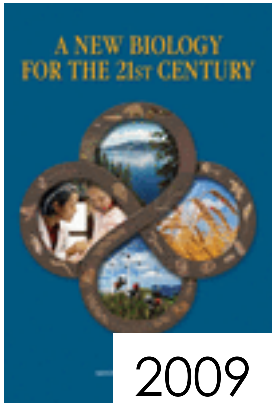
2000



2003



2008



2009

2011

Conclusions:

- Biology has changed.
- "Traditional" instruction isn't preparing students for contemporary biology.

AAAS 2011, Vision and Change In Undergraduate Biology Education: A Call to Action.

Systems Thinking Skills:

- Identify relevant system components and processes
- Organize into a meaningful framework, based on system interactions
- Understand dynamic nature of interactions that traverse scales of space and time (e.g., system feedbacks, cycles)
- Identify and predict emergent properties

(Pennisi 2003; Ben-Zvi Assaraf & Orion 2005; Stave & Hopper 2007)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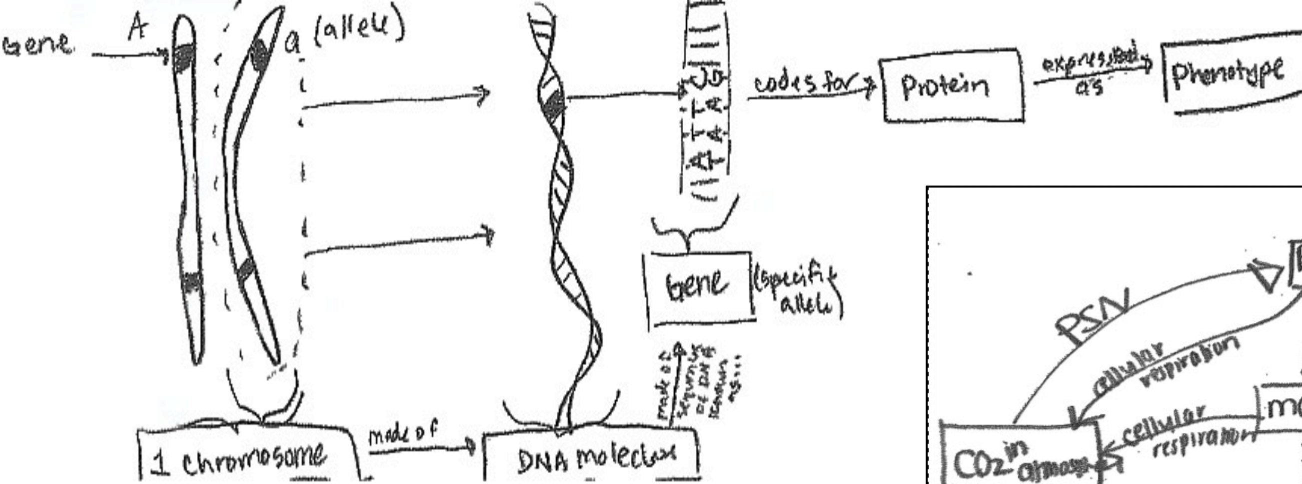
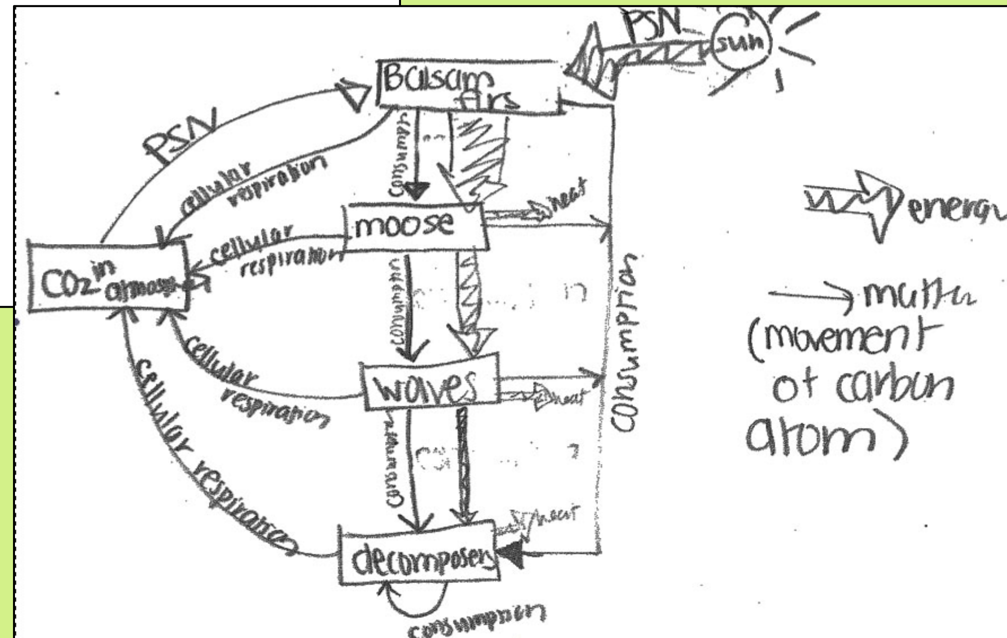
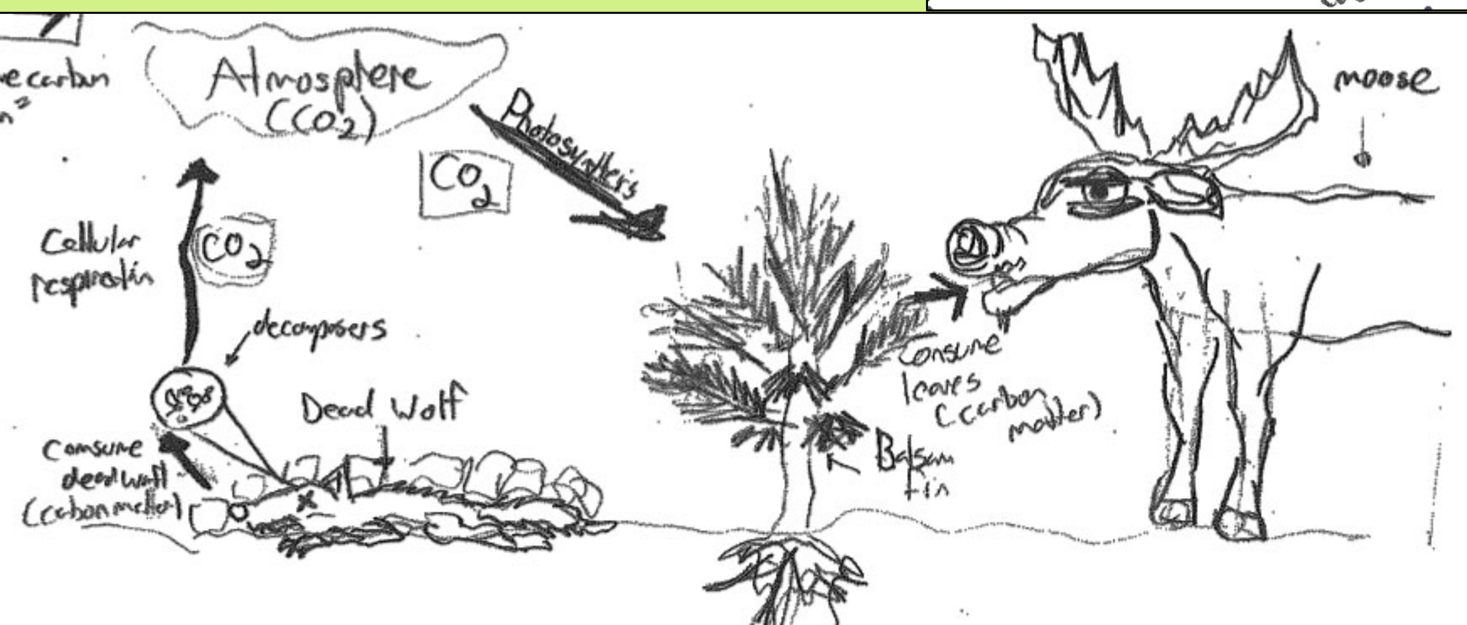
Measuring systems thinking??

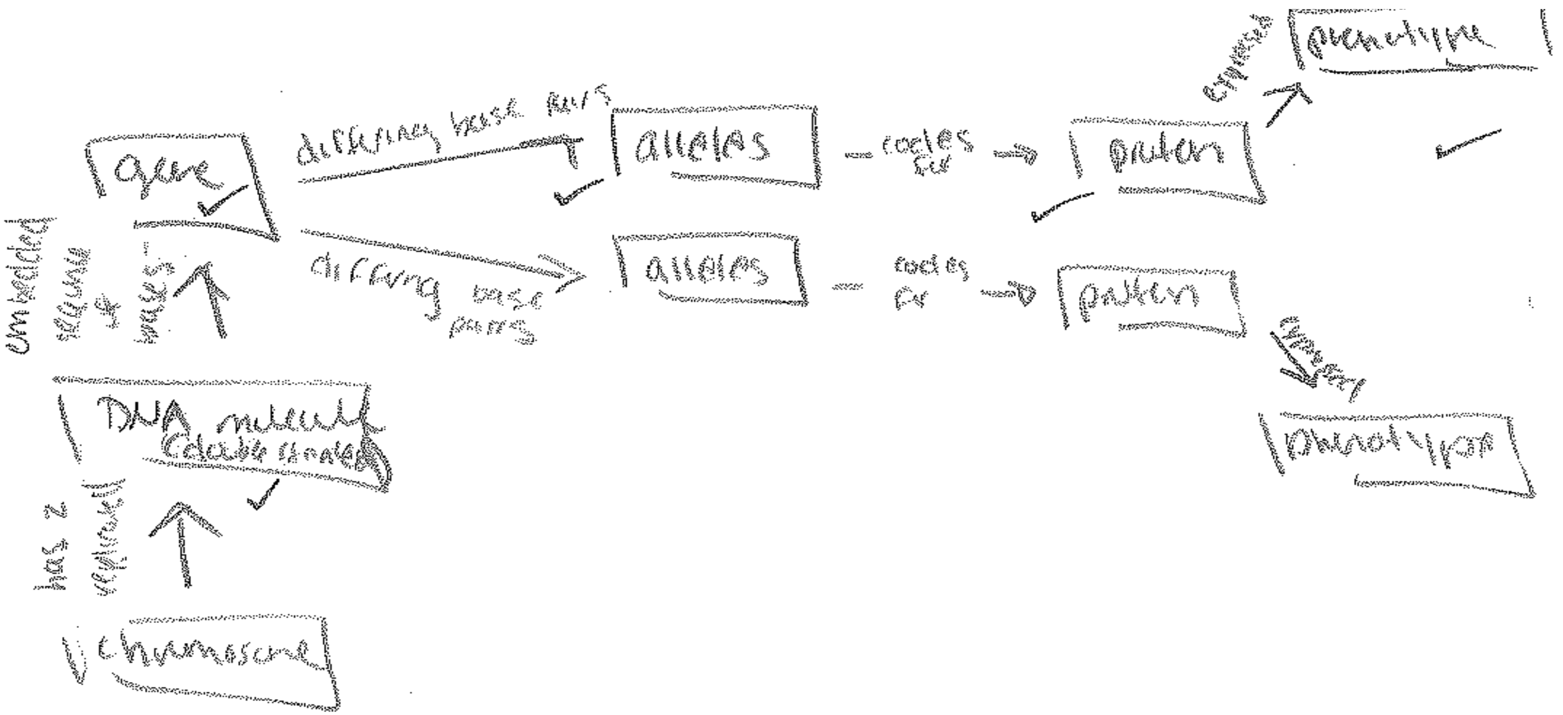

Gene
A
a (allele)
codes for
Protein
expressed as
Phenotype
Gene (specific allele)
1 chromosome
made of
DNA molecule


PSN
sun
Balsam firs
PSN
cellular respiration
consumption
moose
heat
cellular respiration
CO_2 in atmosp
consumption
cellular respiration
wolves
heat
cellular respiration
consumption
consumption
heat
decomposers
consumption
energ
matter
(movement of carbon atom)


Atmosphere (CO_2)
Photosynthesis
CO_2
moose
Cellular respiration
CO_2
decomposers
Dead Wolf
consume dead wolf (carbon matter)
consume leaves (carbon matter)
Balsam fir

What is a system model?

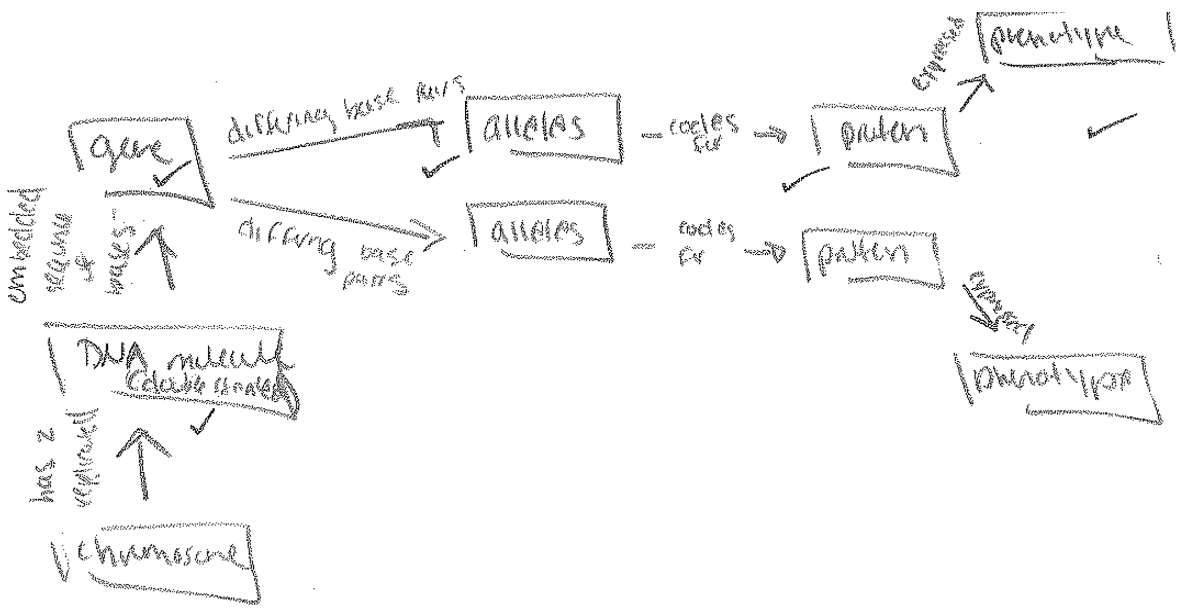
- Adapted from Structure-Behavior-Function Theory (SBF; Goel et al. 1996)



Goel (1996): Models have

Structures System components, concepts (nouns)

Behaviors → System processes, relationships (verbs)



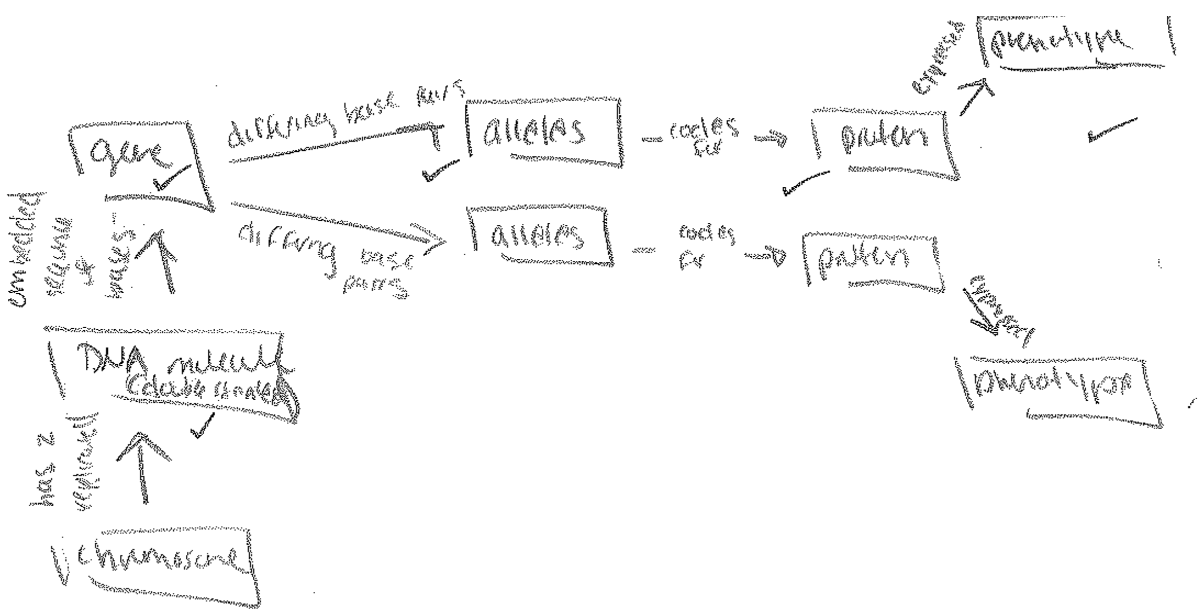
Function: output, role, purpose of a system

(Adapted from Goel et al. 1996)

System models have 3 elements:

~~Structures~~ | System components, concepts (nouns) | **Concepts (Components)**

~~Behaviors~~ → | System processes, relationships (verbs) | **Relationships** →



Function: output, role, purpose of a system

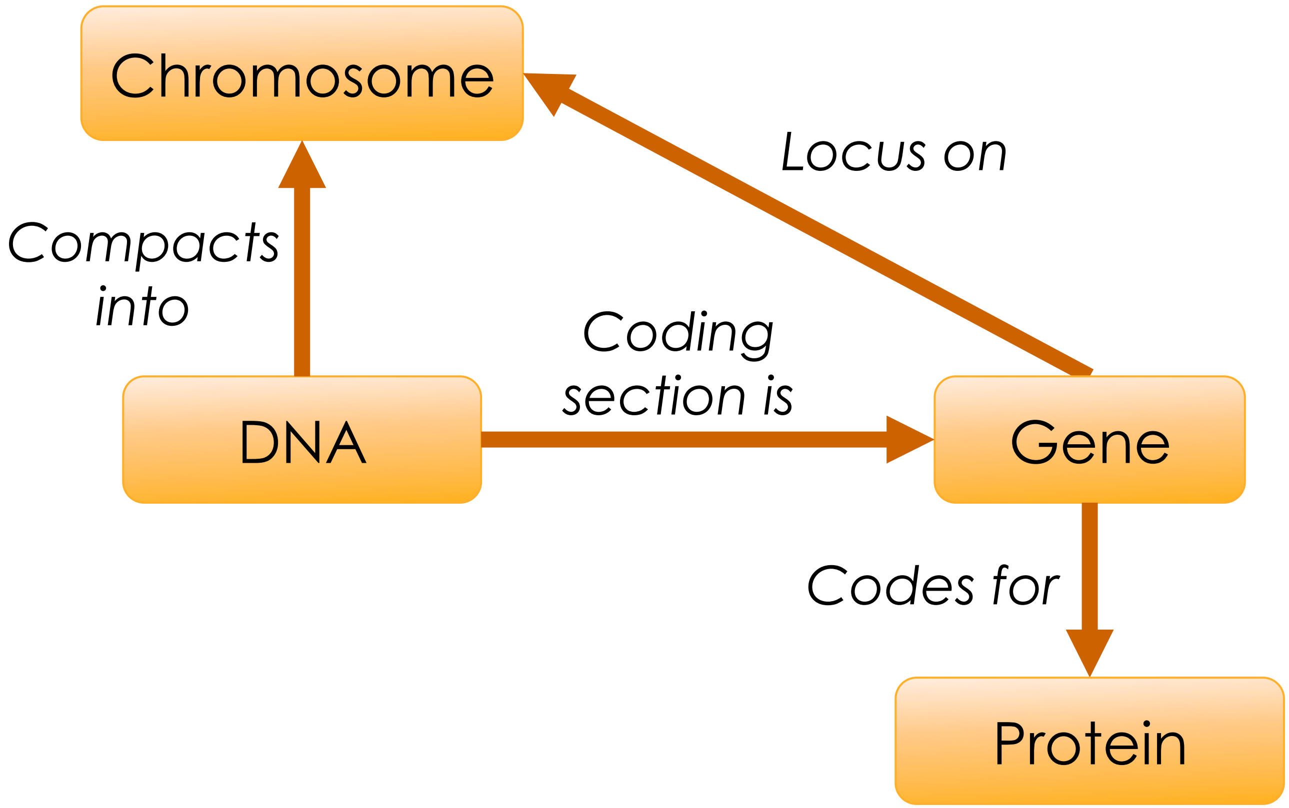
Rules for constructing a system model:

- Concepts (nouns) go in boxes
- Process/relationships (verbs) go on arrows
- Arrows are directional
- Propositions must stand alone

Draw a system model that:

(a) includes the concepts:
Gene, **DNA**, **Chromosome**, **Protein**

(b) has the function of showing how genetic information is organized and expressed



Compare with your neighbor.

How was your thinking *different* from. . .

A gene is:

(a) A section of DNA
(b) A trait you inherit from your parents
(c) . . .

Modeling/Models:

- Focus attention on relationships among concepts (Vattam et al. 2011)
  - Characteristic of experts; novices focus on concepts (Hmelo-Silver et al. 2007)
- Drawing improves scientific reasoning compared to textual representations (Löhner et al. 2005)
- Align (significantly!) with concepts and competencies articulated in V&C and NGSS
- Promote systems thinking skills - ??

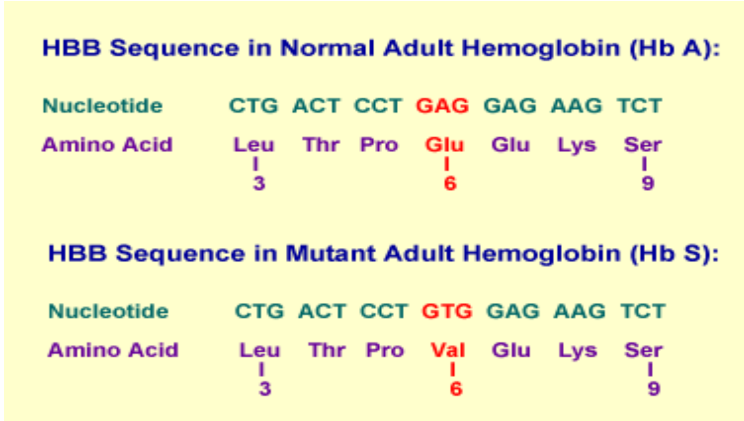
Classroom applications

Early in semester:

Construct a system model that shows relationships among the following concepts:

- Gene
- Chromosome
- DNA

Midterm Exam and Later:

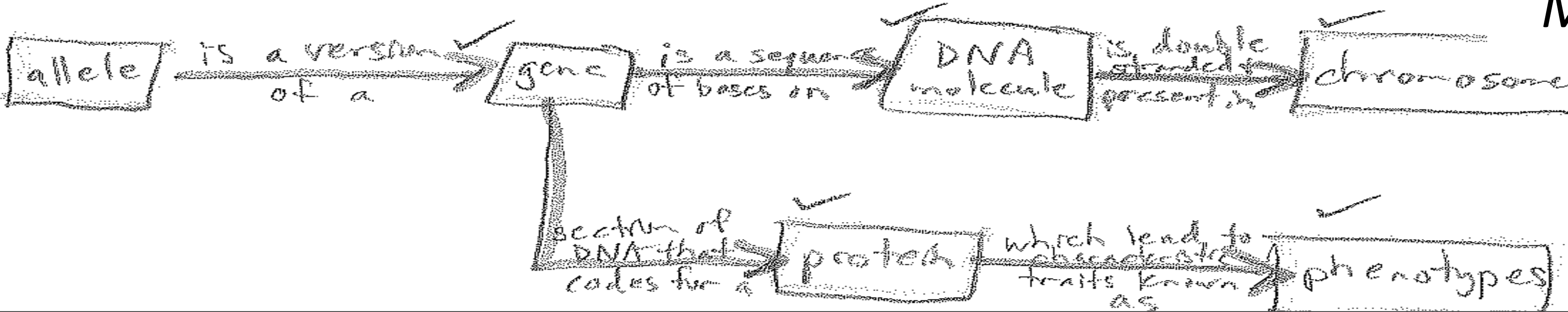


Using the concepts below, construct a system model for the hemoglobin-mosquito case. A correct model must explain:

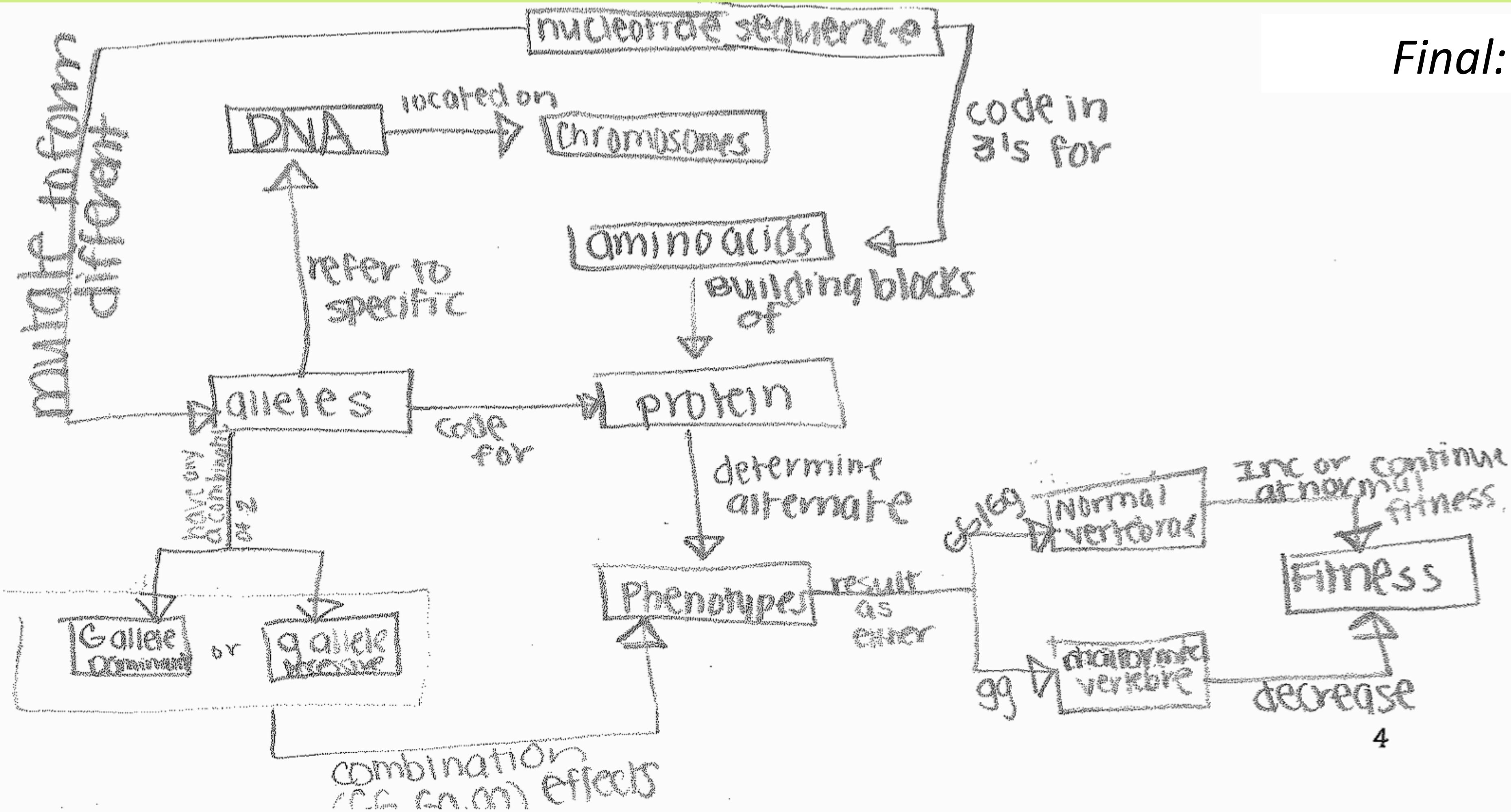
a) how genetic variation originates and is expressed;
b)
c) the consequences of phenotypic variation on fitness within the population.

- Gene
- Chromosome
- Protein
- Nucleotide
- Phenotype
- Population change
- DNA
- Allele
- Fitness

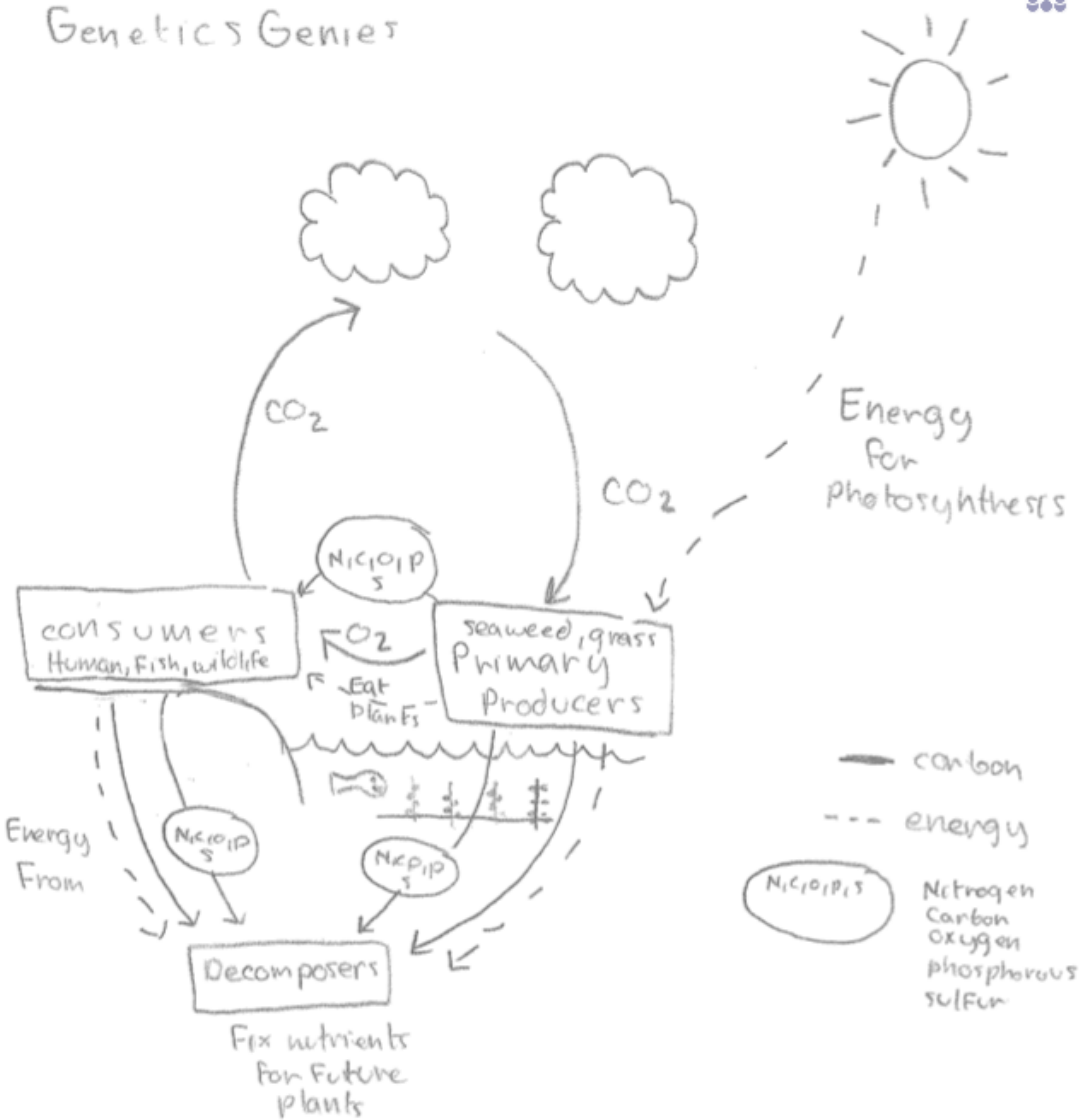
Midterm:



Final:



- Construct a model or drawing that explains how a carbon atom in a wolf could become part of the body of a moose.


Genetics Genies
CO_2
CO_2
Energy for Photosynthesis
N, C, O, P S
consumers
Human, Fish, wildlife
O_2
Eat plants
seaweed, grass
Primary Producers
carbon
energy
Energy From
N, C, O, P S
N, C, P, P S
N, C, O, P, S
Nitrogen
Carbon
Oxygen
phosphorous
sulfur
Decomposers
Fix nutrients for Future plants

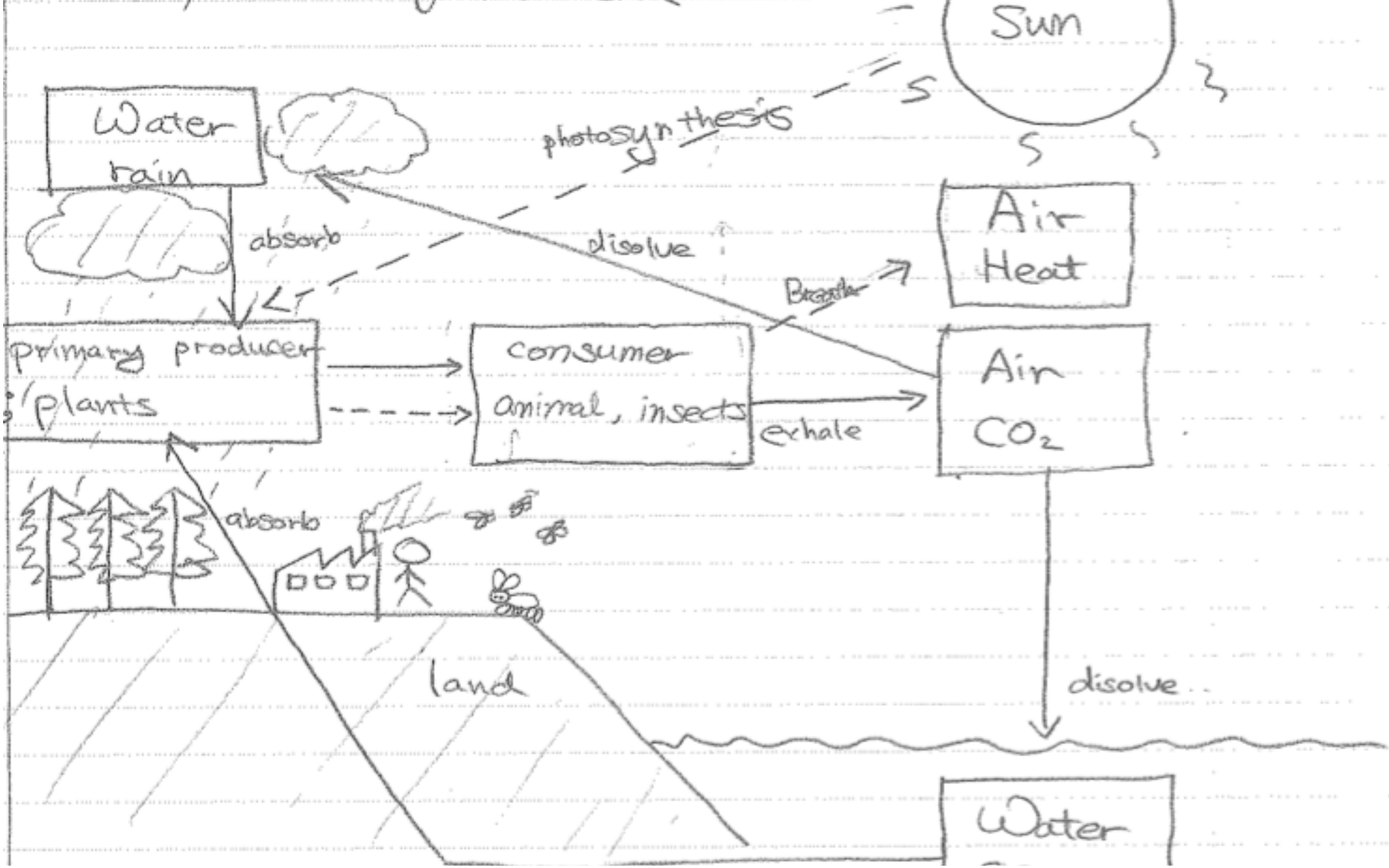
⟶ : movement of matter

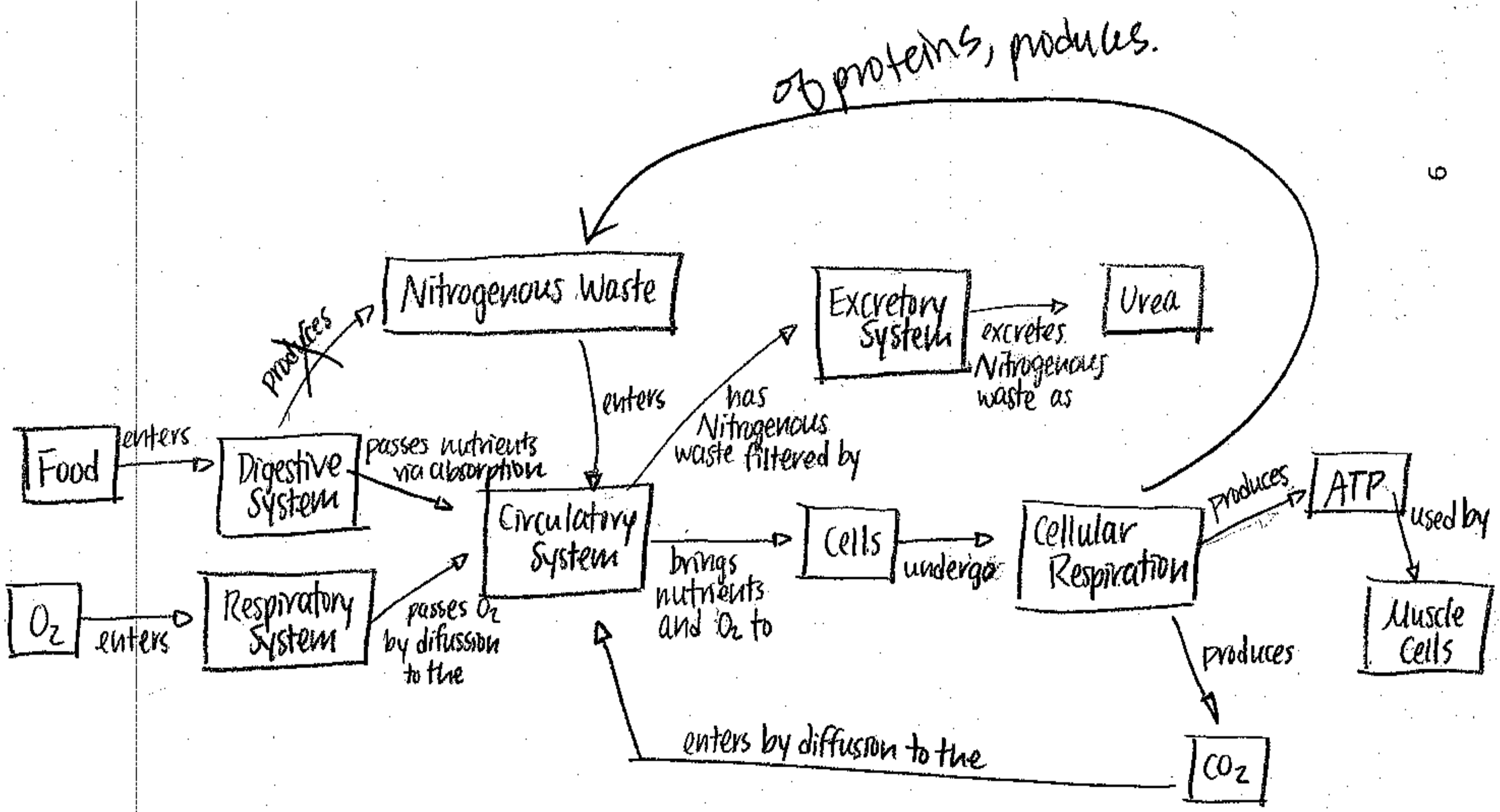
- - -> : movement of energy

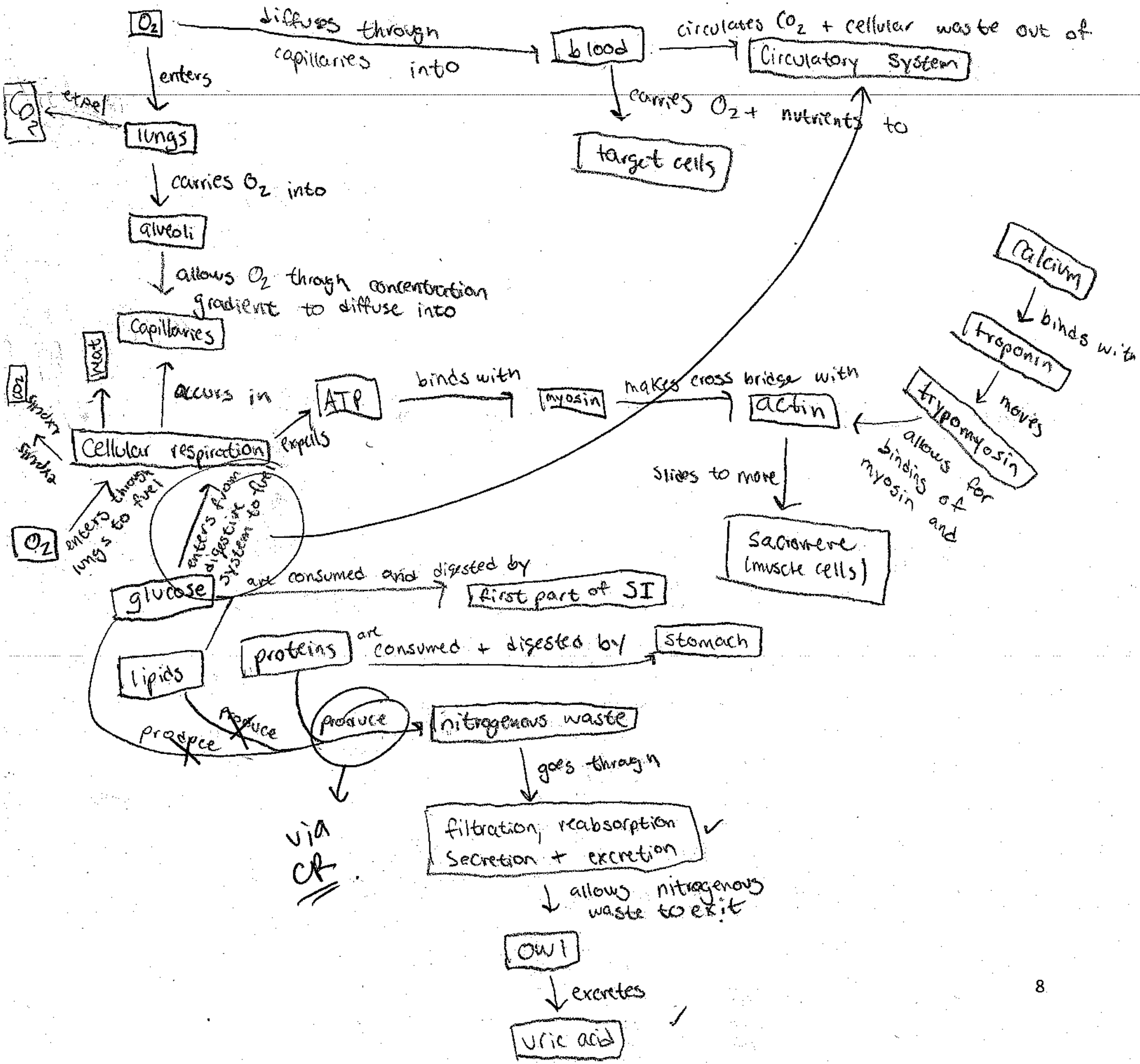
primary produser : plant

consumer : animal, insect

decomposer : fungi , Bacteria




of proteins, produces.
Nitrogenous Waste
produces
Excretory System
excretes Nitrogenous waste as
Urea
enters
has Nitrogenous waste filtered by
Food
enters
Digestive System
passes nutrients via absorption
Circulatory System
Cells
undergo
Cellular Respiration
produces
ATP
used by
Muscle Cells
O_2
enters
Respiratory System
passes O_2 by difussion to the
brings nutrients and O_2 to
produces
CO_2
enters by diffusion to the



O_2
diffuses through capillaries into
blood
circulates CO_2 + cellular waste out of
Circulatory System
carries O_2 + nutrients to
target cells
enters
lungs
CO_2
carries O_2 into
alveoli
allows O_2 through concentration gradient to diffuse into
Capillaries
heat
occurs in
ATP
binds with
myosin
makes cross bridge with
actin
Cellular respiration
expells
expels
CO_2
O_2
enters through lungs to fuel
enters from digestive system to fuel
glucose
are consumed and digested by
first part of SI
proteins
are consumed + digested by
stomach
lipids
produce
produce
produce
nitrogenous waste
via CR
goes through
filtration, reabsorption Secretion + excretion
allows nitrogenous waste to exit
owl
excretes
Uric acid
calcium
binds with
troponin
moves
trypomyosin
allows for binding of myosin and
slides to move
sacromere (muscle cells)

Systems Thinking Skills:

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- Identify and predict emergent properties

(Pennisi 2003; Ben-Zvi Assaraf & Orion 2005; Stave & Hopper 2007)

Concept maps vs. System Models

Purpose	Domain of knowledge	Function, process
Linkages	Associations	Mechanistic
Growth	Expansive	Parsimony
Hierarchy	Yes	No

Tips for best practice:

- Early and often
- Practice with feedback
  - Peers
  - Instructor
- Transparent rubrics
- Diverse contexts, applications

Acknowledgements

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