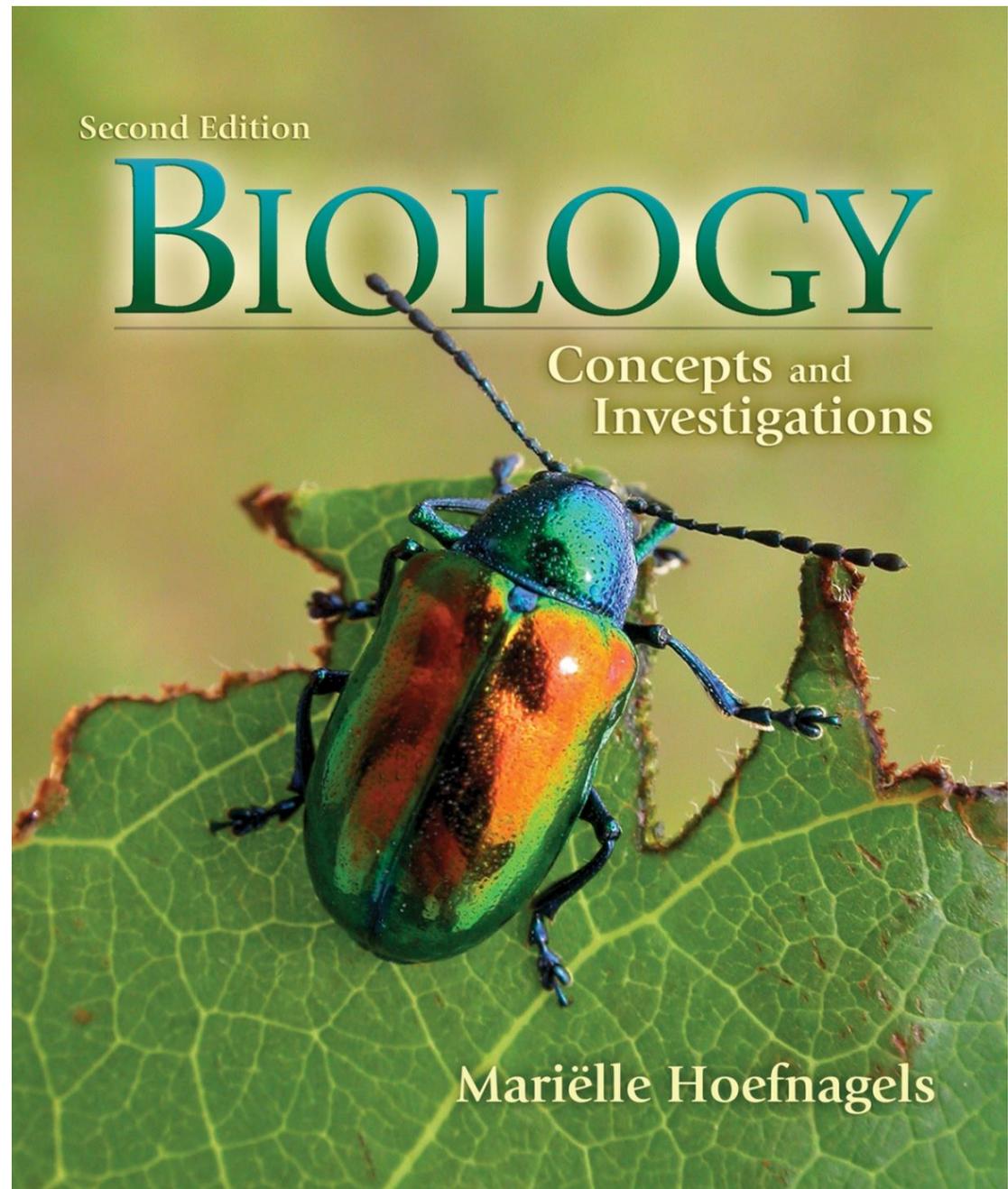


Chapter 01

Images for Students



Learning Objectives

1. Describe the characteristics shared by all living organisms.
2. Compare and contrast the three branches of life.
3. Identify standardized, dependent, and independent variables in an experiment.
4. Apply the scientific method to analyze data.
5. Discuss the limitations of the scientific method.

What defines life?



What is life?

Alive?



Alive?



What is life?

- One way to define life is to list its basic components
- Every living thing is made of **cells**
- Every **organism** consists of one or more cells
- **What characteristics do you think must occur in every cell?**
- **Do these characteristics make an organism alive?**
- Thus life defies a one sentence answer/definition

What is life?

- Thus life defies a one sentence answer/definition
- Instead, life is recognized by what living things do and can be categorized into **5 properties of life**
- **Life is Organized**
- **Life Requires Energy**
- **Life Self Regulates**
- **Life Reproduces Itself, Grows, and Develops**
- **Life Adapts & Evolves**

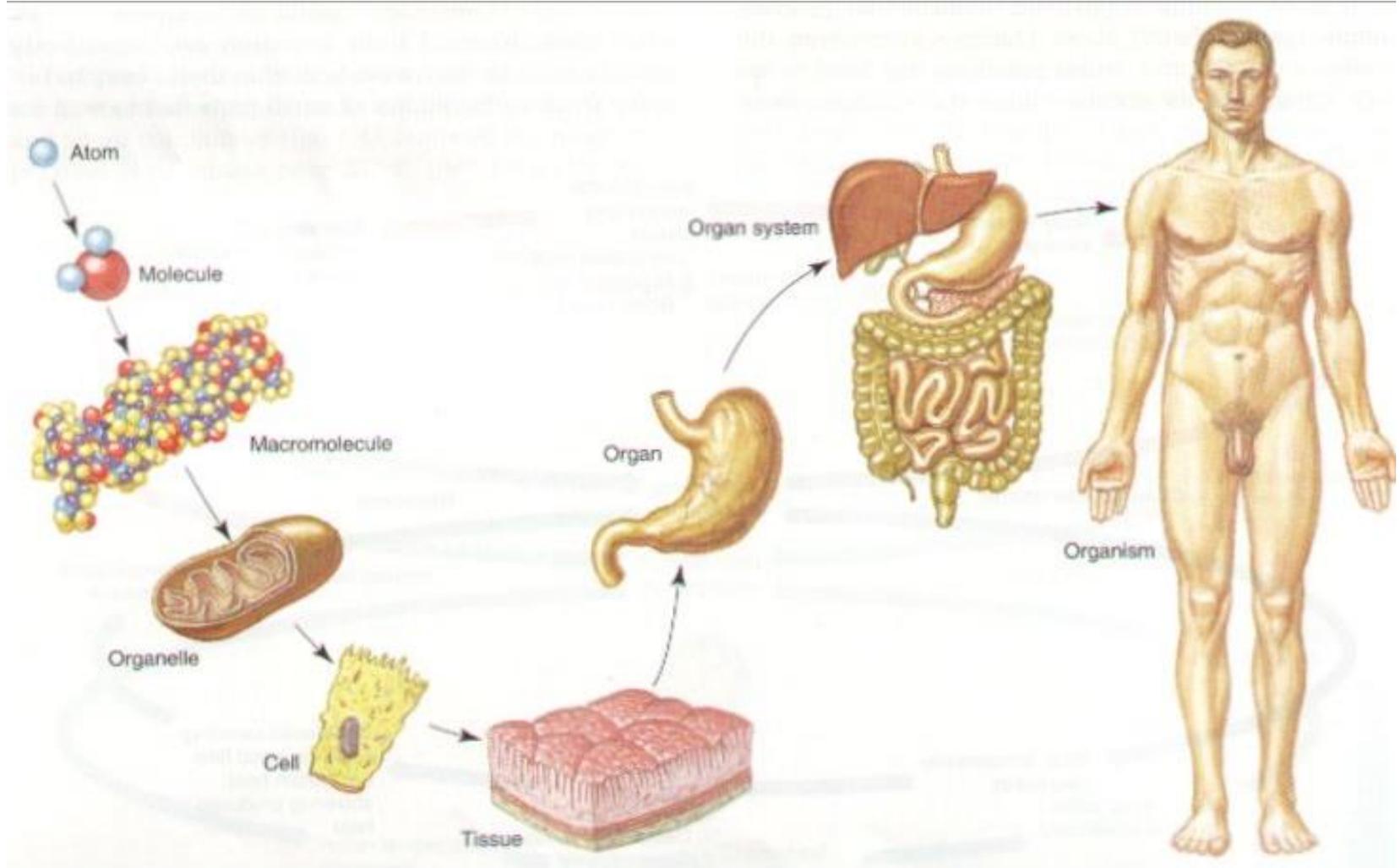
Summary: What is life?

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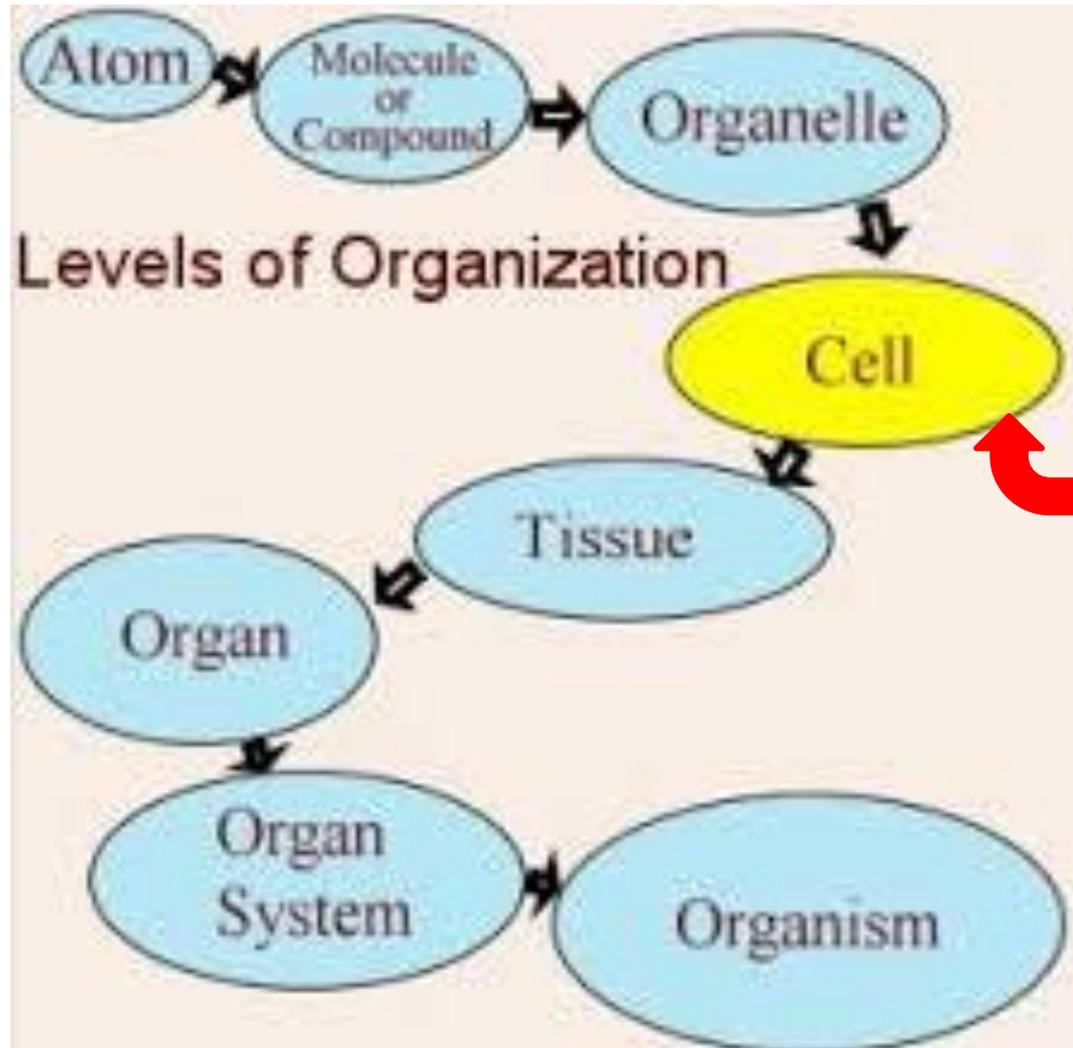
Table 1.1 Characteristics of Life: A Summary

Characteristic	Example
Organization	Atoms make up molecules, which make up cells, which make up tissues, and so on.
Energy use	A kitten uses the energy from its mother's milk to fuel its own growth.
Maintenance of internal constancy	Your kidneys regulate your body's water balance by adjusting the concentration of your urine.
Reproduction, growth, and development	An acorn germinates, develops into an oak seedling, and, at maturity, reproduces sexually to produce its own acorns.
Evolution	Increasing numbers of bacteria survive treatment with antibiotic drugs.

Life is Organized

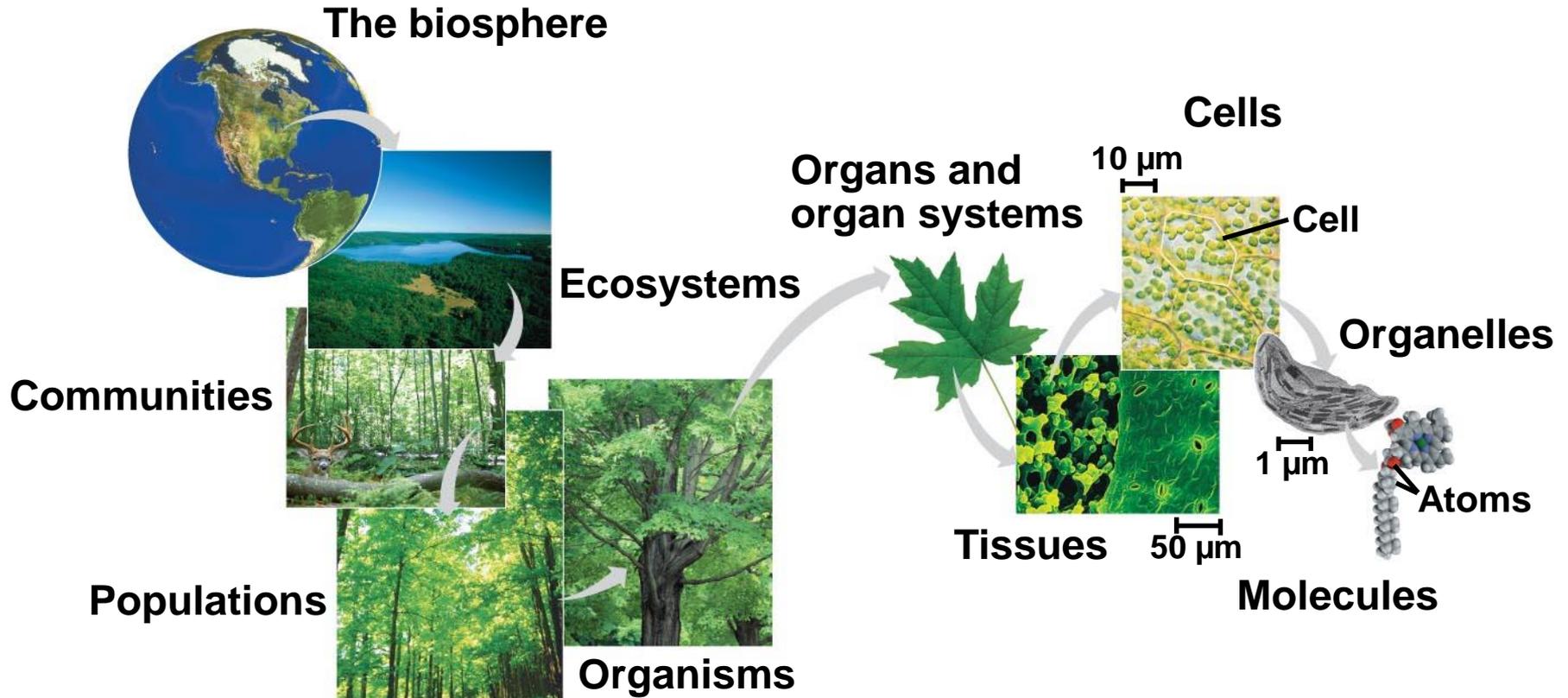


Life is Organized



**Fundamental
unit of life**

Life is Organized



The biosphere

Communities

Populations

Ecosystems

Organisms

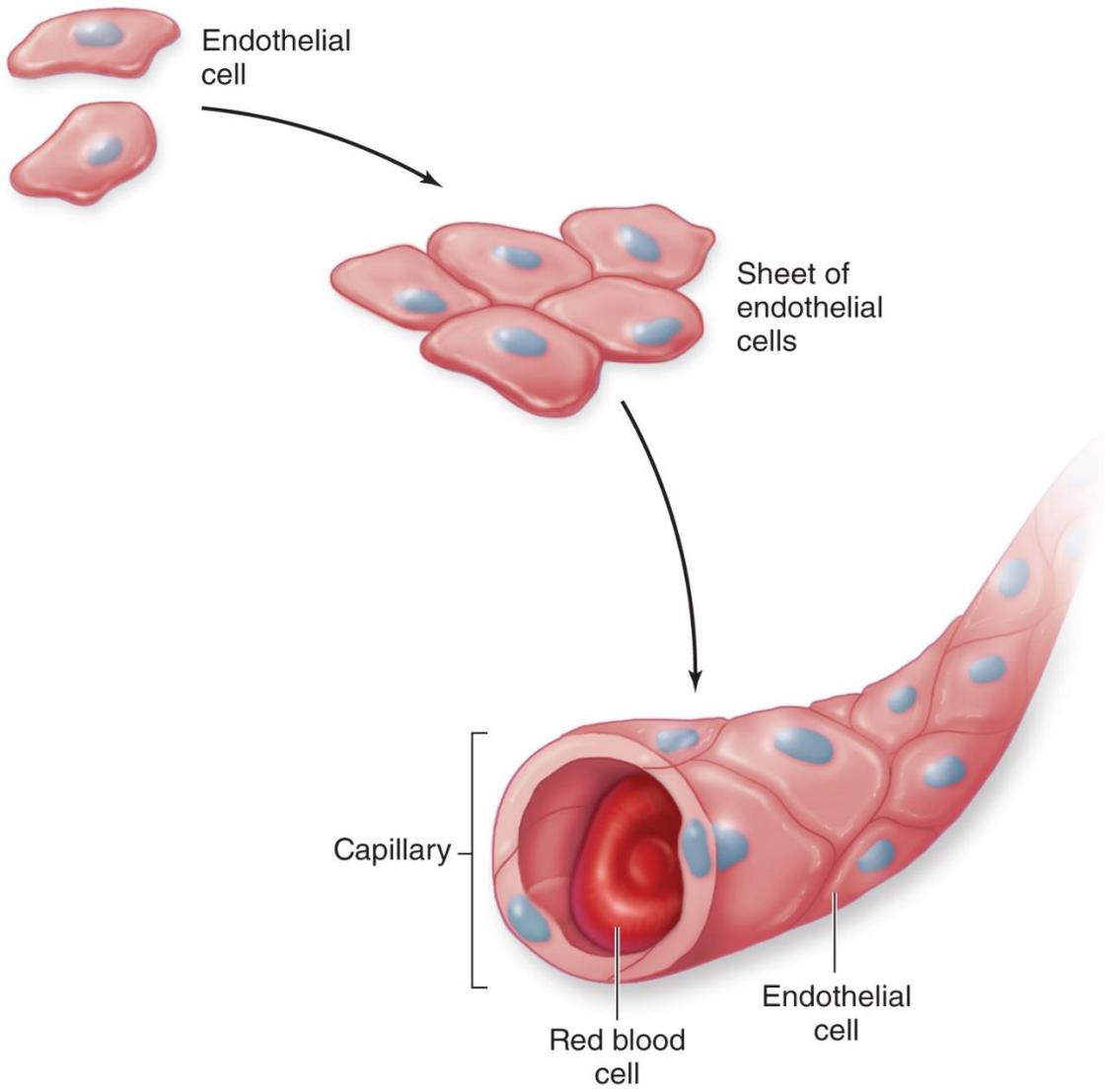
**O
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- **Emergent properties** result from the arrangement and interaction of parts within a system
- Emergent properties characterize non-biological entities as well
 - For example, a functioning bicycle emerges only when all of the necessary parts connect in the correct way or when you add flour, sugar, butter and chocolate make brownies (something not evident from the parts themselves) aka **synergism**

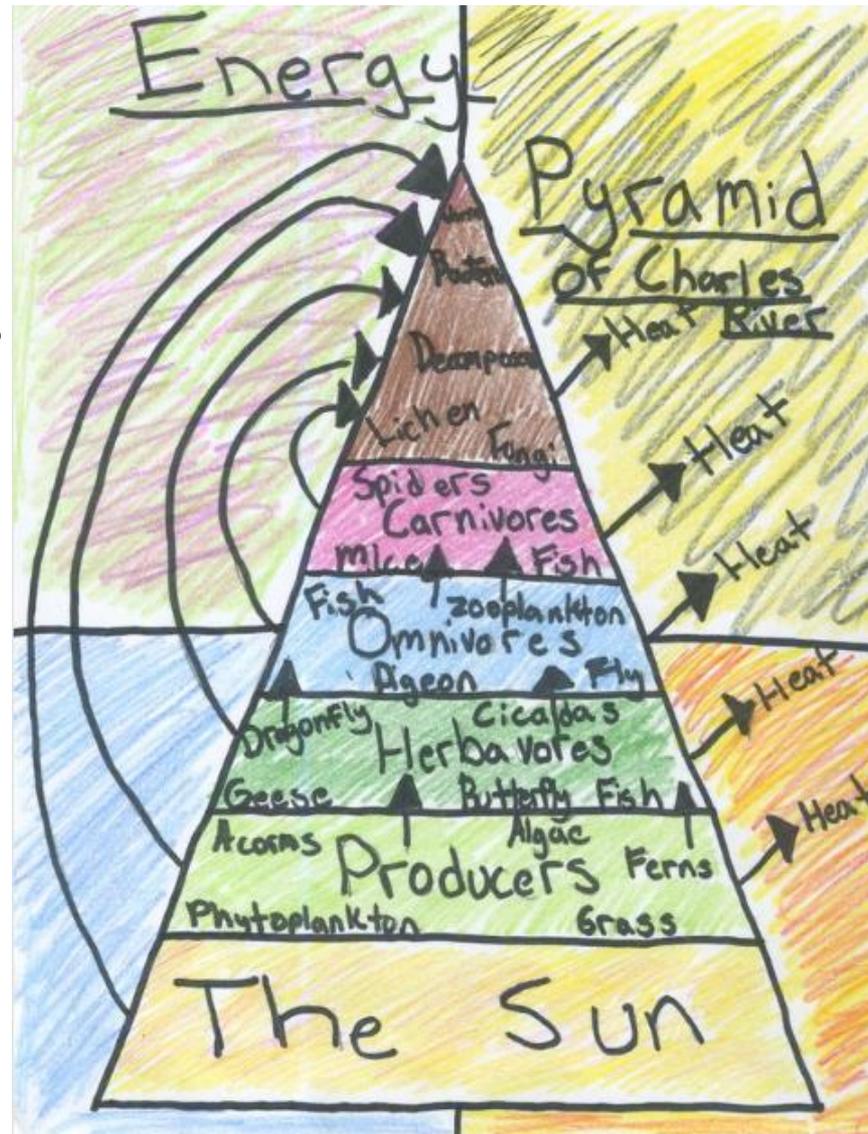
Biological Examples of Emergent Properties

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Life Requires Energy

Ever heard of the rule of 10's?



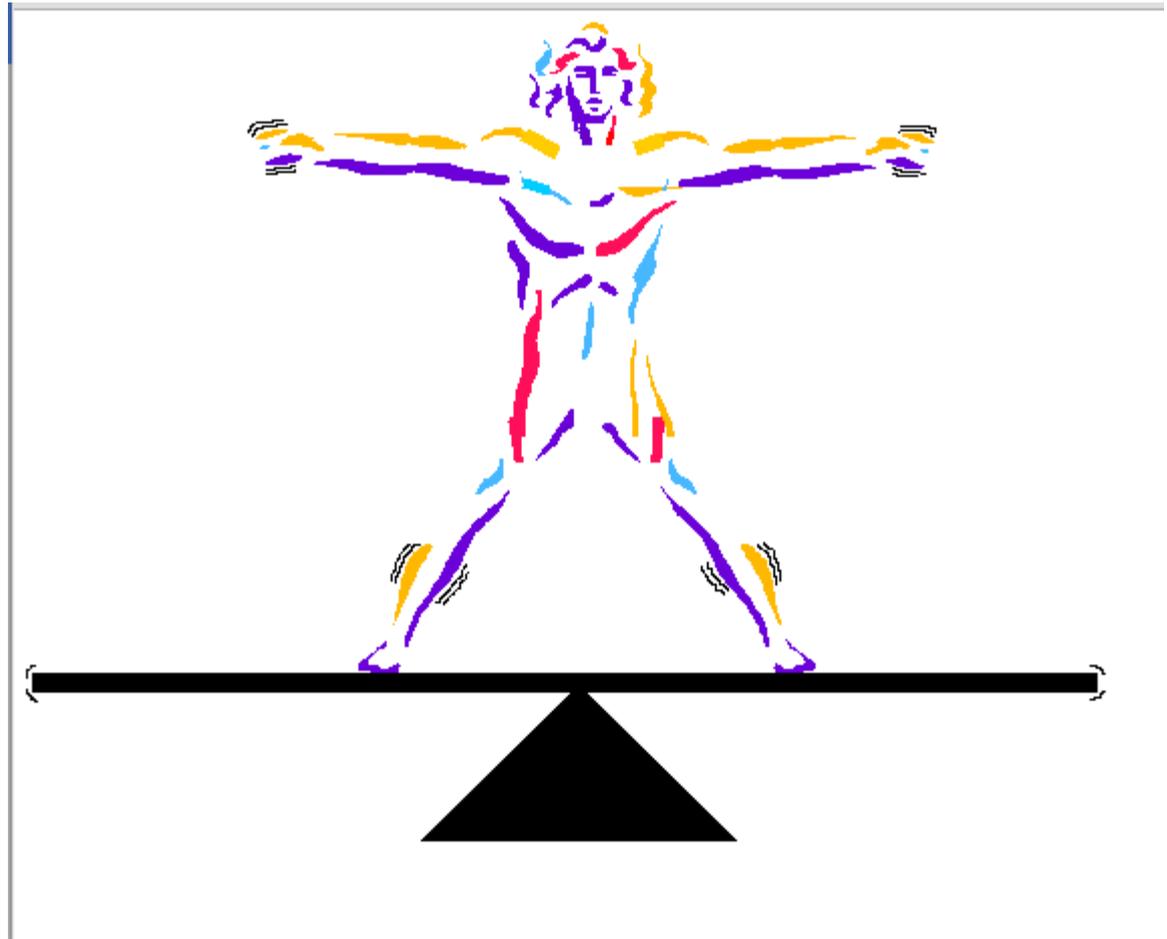
Life Self Regulates

Homeostasis-
Cell/organism
maintains state of
equilibrium

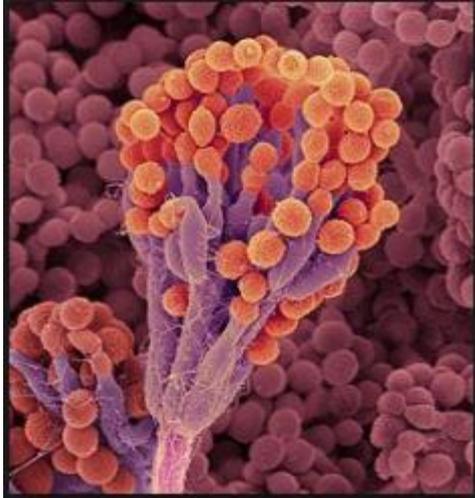
Example:

[Kangaroo](#)

Other Examples?



Life Reproduces Itself, Grows and Develops



***Pencilium* spores**



Coconut tree seedling



Fawn product of sexual reproduction

Asexual reproduction

- Genetic info from 1 parent
- Virtually identical
- Reproduce quickly
- Ex. Strawberry plant' s, fungi & bacteria

Sexual reproduction

- Genetic info from 2 parents
- Genetically unique
- Reproduce slower
- Ex. Mammals, Reptiles, Birds

Life Evolves

- Evolution makes sense of everything we know about living organisms
- Organisms living on Earth are modified descendants of common ancestors

What do we call inherited characteristics that increase survival chances?

Adaptations

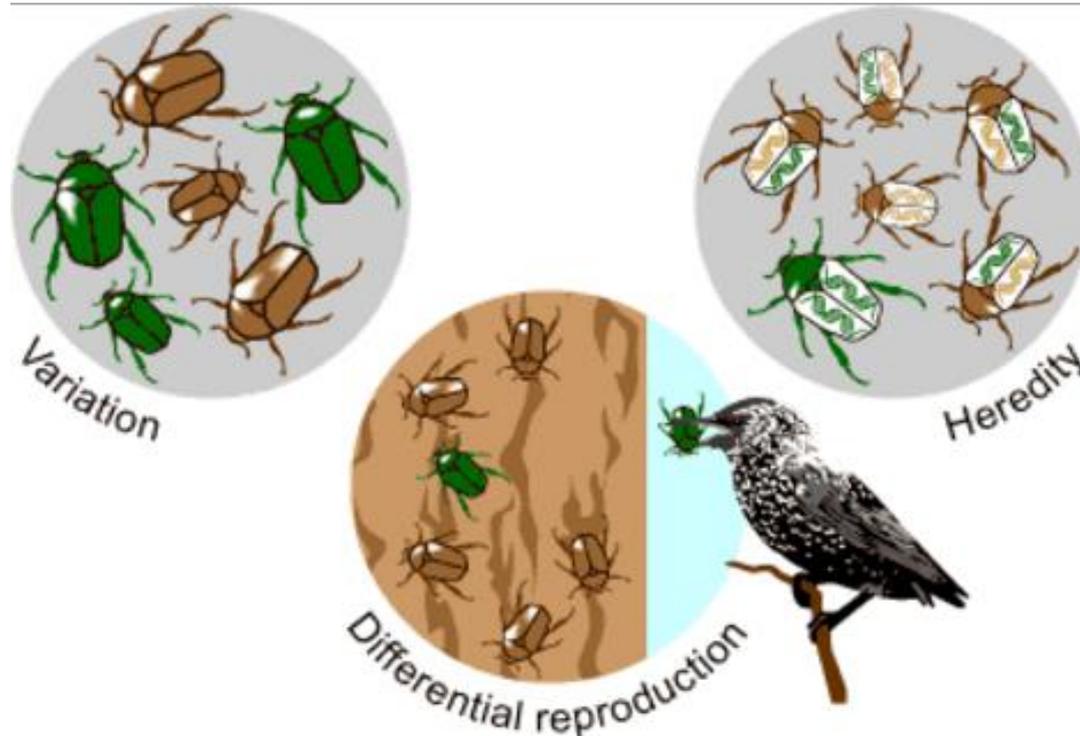


If you know that the orchid shown here has nectar at the bottom of this 8.5 inch calyx, what do you deduce about the flower's pollinator?



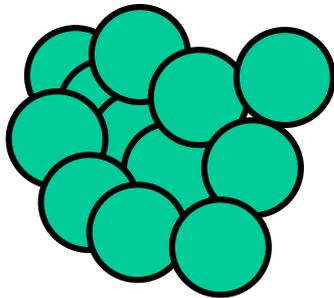
Where do adaptations arise?

- **Competition** (aka survival of the fittest) and **Genetic Variation** (aka mutations)
- These two components are some of the key driving forces in **natural selection**



Natural Selection in Bacteria

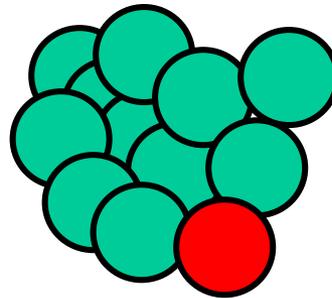
Generation 1



Staphylococcus
before mutation

Time
→

Generation 2

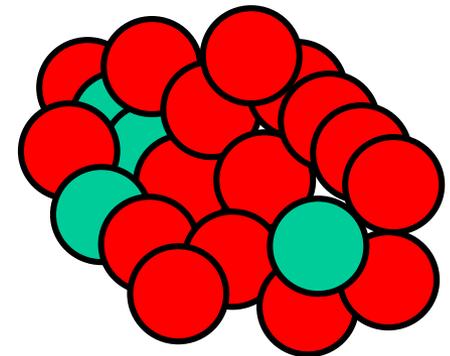


Mutation (red)
occurs

Time
→

Selection
occurs

Generation x



Antibiotic-resistant
bacteria more
successful

Are we good so far?

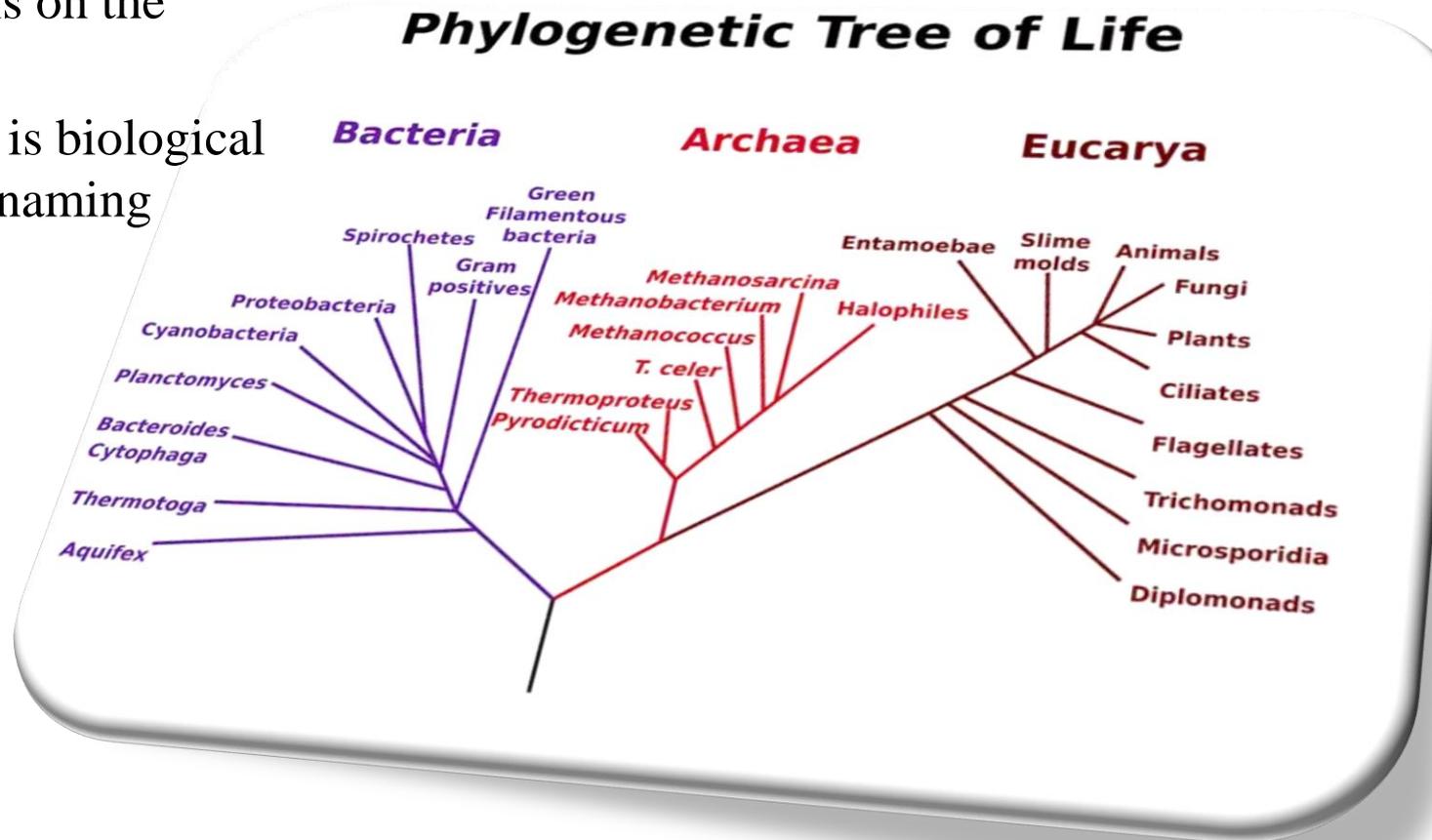


Are we good so far?

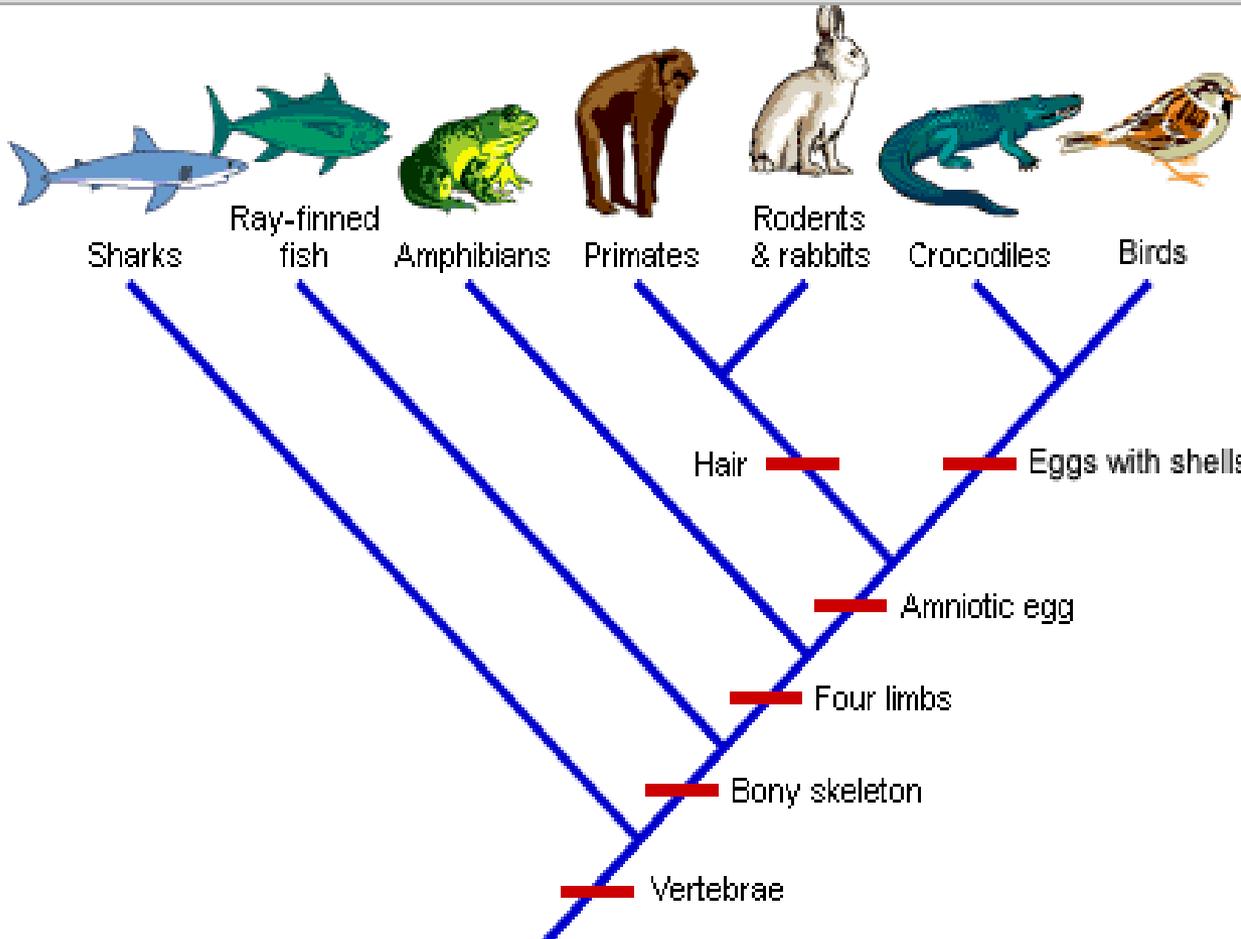
- **What characteristics distinguish the living from the nonliving?**
- **Do you know the level of how life is organized from the smallest (atom) to the largest (biosphere)?**
- **What are the roles of natural selection and mutations in evolution?**

Tree of Life

- According to Biblical text, man's job was to classify all the plant and animals on the Earth
- **Taxonomy** is biological science of naming organisms

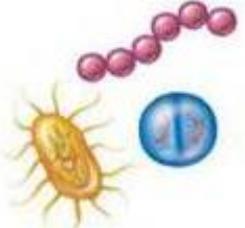


Tree of Life



- **Taxonomy** is more than simply naming organisms.
- The difficult task taxonomists have is **determining the evolutionary relationship** of who is related to whom
- The more **recently** two organisms **diverged** from one another, the **more similar** the two should be.

Tree of Life: The Big Three

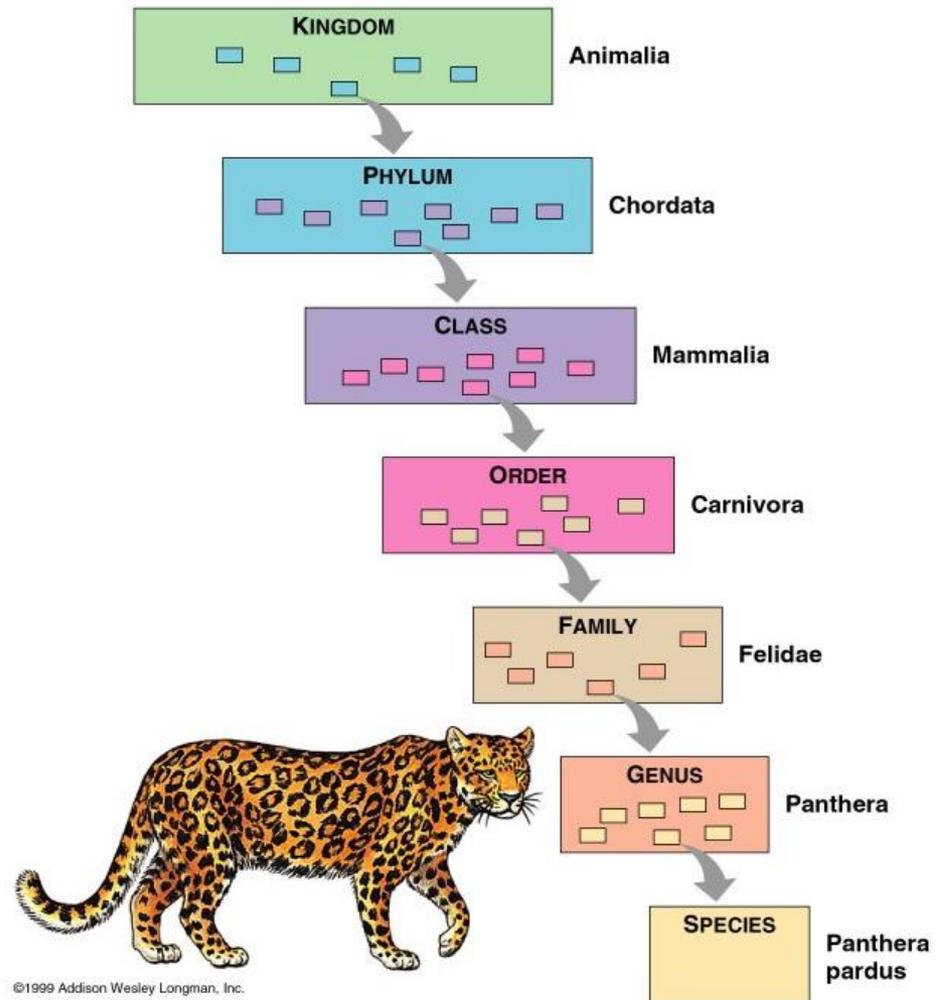
Domain Bacteria	Domain Archaea	Domain Eukarya			
Unicellular prokaryotic organisms	Unicellular prokaryotic organisms; most live in extreme environments	Eukaryotic cells that contain a membrane-bound nucleus and internal compartments			
					
<div style="background-color: yellow; padding: 10px;"> <p>DNA sequences vary significantly</p> </div>		Kingdoms			
		Protists	Fungi	Plants	Animals
		Protozoans, algae, diatoms	Molds, mushrooms	Mosses, ferns, seed plants	Invertebrates and vertebrates

Do you know some similarities and differences between all 3 domains?

Tree of Life: Levels of Classification

- After Domain, taxonomist further divide life into smaller and smaller categories.

- King- Kingdom
- Philip- Phylum
- Came- Class
- Over- Order
- For- Family
- Good- Genus
- Spaghetti- species



We still good to go?

- **What are the goals of taxonomy?**
 - classify organisms according to evolutionary history*
- **How are domains related to kingdoms?**
 - *category in which scientist try to maximize the likelihood of as many organisms as possible*
- **List and describe the four main groups within eukaryotes.**
 - Plants, Animals, Fungi, Protists*

Scientific Inquiries and Understanding the Scientific Method

- What is it?
 - Stepwise methods to find answers to scientific questions
 - A repeatable process for finding scientific evidence of natural phenomena

- How we do it?
 - There are 7 steps in a scientific method.
 1. *Make Observations*
 2. *State Key Question*
 3. *State Hypothesis*
 4. *State Prediction*
 5. *Conduct Scientific Investigation*
 6. *Analyze Results*
 7. *Form Conclusion*

Steps of Scientific Method

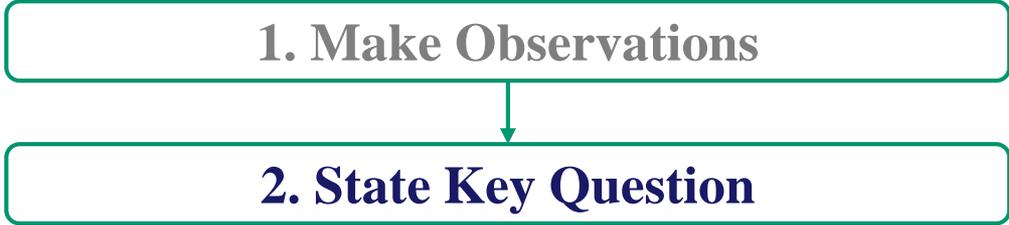
1. Make Observations

Example of observation:

You make observations and the general observation suggests:

“Fertilization might promote the growth of the plants.”

Steps of Scientific Method



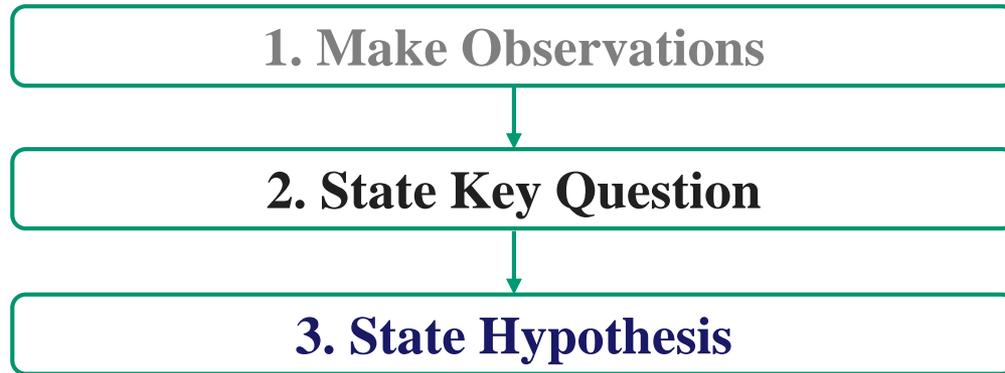
After observation you raise the question.

Example of Key Question:

“Does fertilization promote the growth of the plants?”

1. *What is the cause of AIDS?*
2. *Is dictatorship evil?*
3. *Why is grass green?*
4. *Does watching television cause children to have shorter attention spans?*
5. *Was the malignant tumor found in the lungs of a 70-year-old man caused by his 45-year habit of smoking cigarettes?*

Steps of Scientific Method



You form a hypothesis about what you think will happen:

Example of Hypothesis

“Fertilization will promote the growth of plants.”

Investigable scientific hypotheses

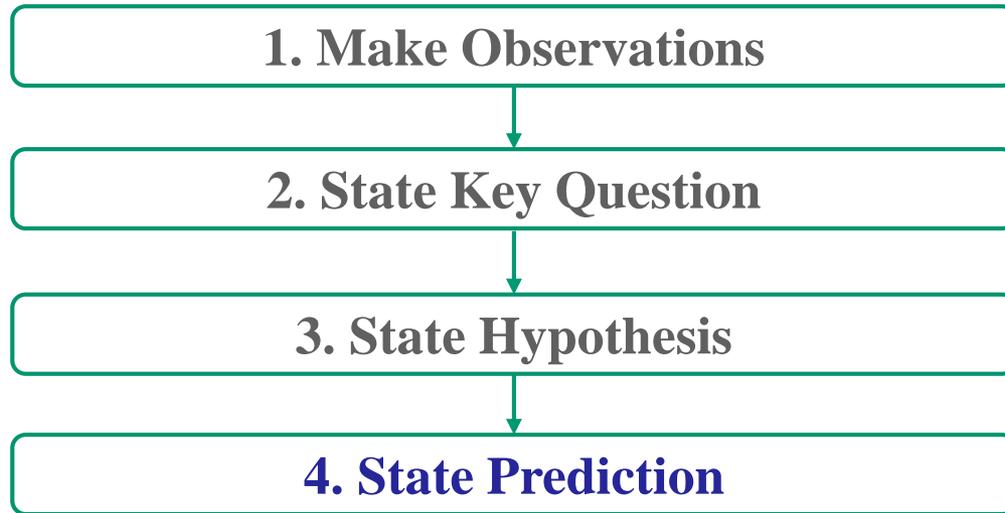
Which of the following would be useful as scientific hypotheses and could be investigated using scientific method. Discuss the reason for each answer by stating whether it could possibly be falsified and what factors are measurable and controllable.

1. *Mice require calcium for developing strong bones.*
2. *Excessively high temperatures cause people to behave immorally.*
3. *Dogs are happy when you feed them steak.*
4. *An active volcano can be prevented from erupting by throwing a virgin into it during each full moon.*
5. *The earth is 4 billion years old.*

- In a TV ad, a pharmaceutical company claimed that the effectiveness of a new drug has been proved clinically .
- Is this claim correct scientifically?
- *The (hypothetical) effectiveness of the new drug has been supported by evidence based on numerous clinical trials.*

Nothing has been proved in science; only supported by evidence and anything can be falsified in the future.

Steps of Scientific Method

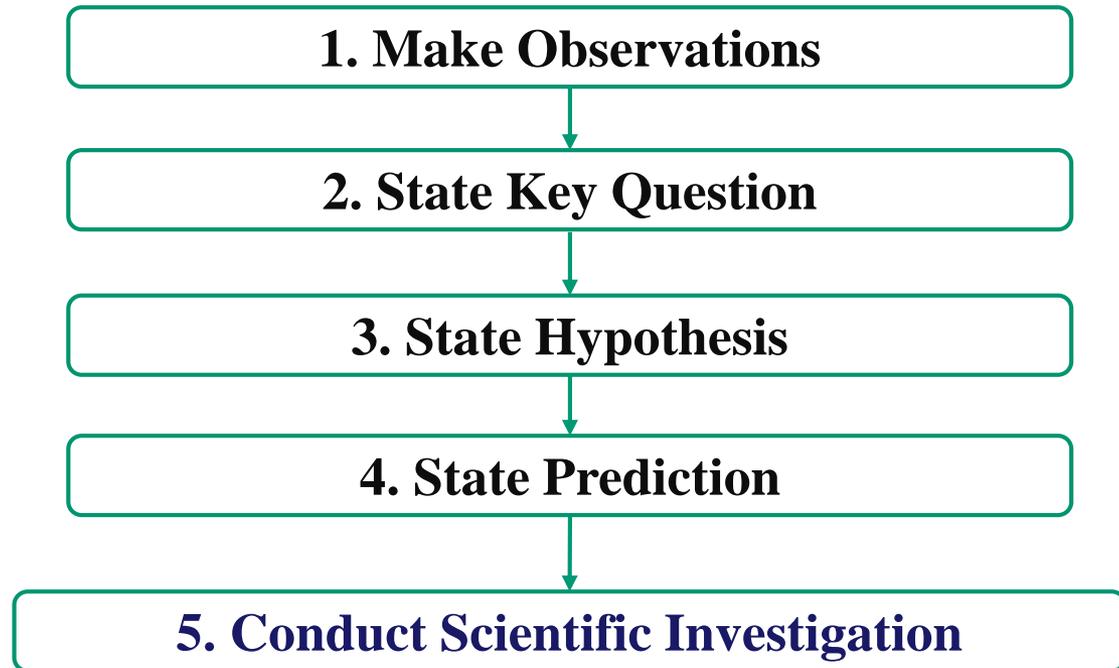


Based on the hypothesis, predict the outcome.

Example of Prediction: (If, then)

“If fertilization promotes the growth of plants, soybean receiving fertilizer will grow taller.”

Steps of Scientific Method



Purpose: to collect data, which support predictions (controlled experiment or numerous observations).

Example of Scientific Investigations:

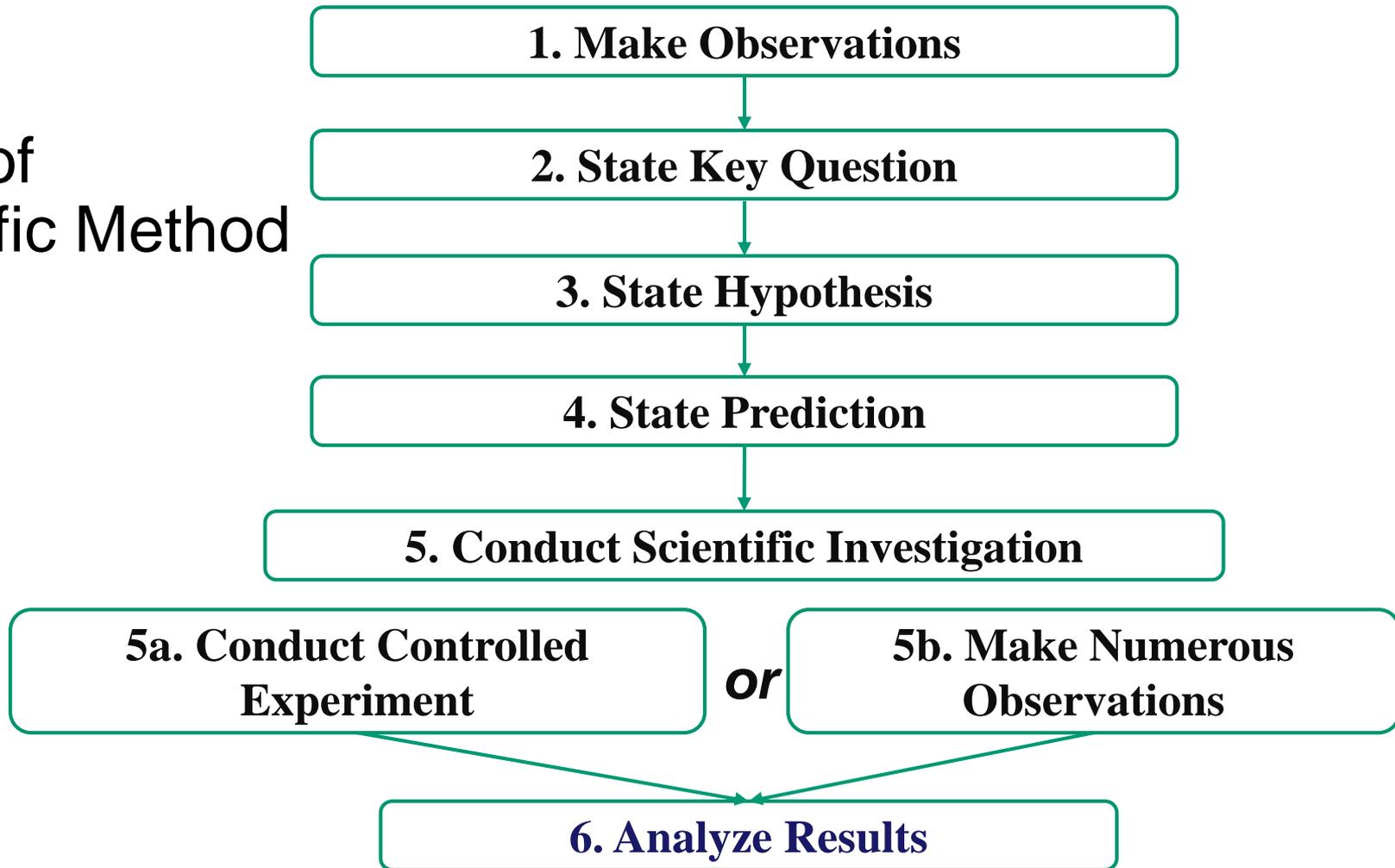
A controlled experiment:

“One group of soybean plants receive fertilizer while not the other”

Numerous observations:

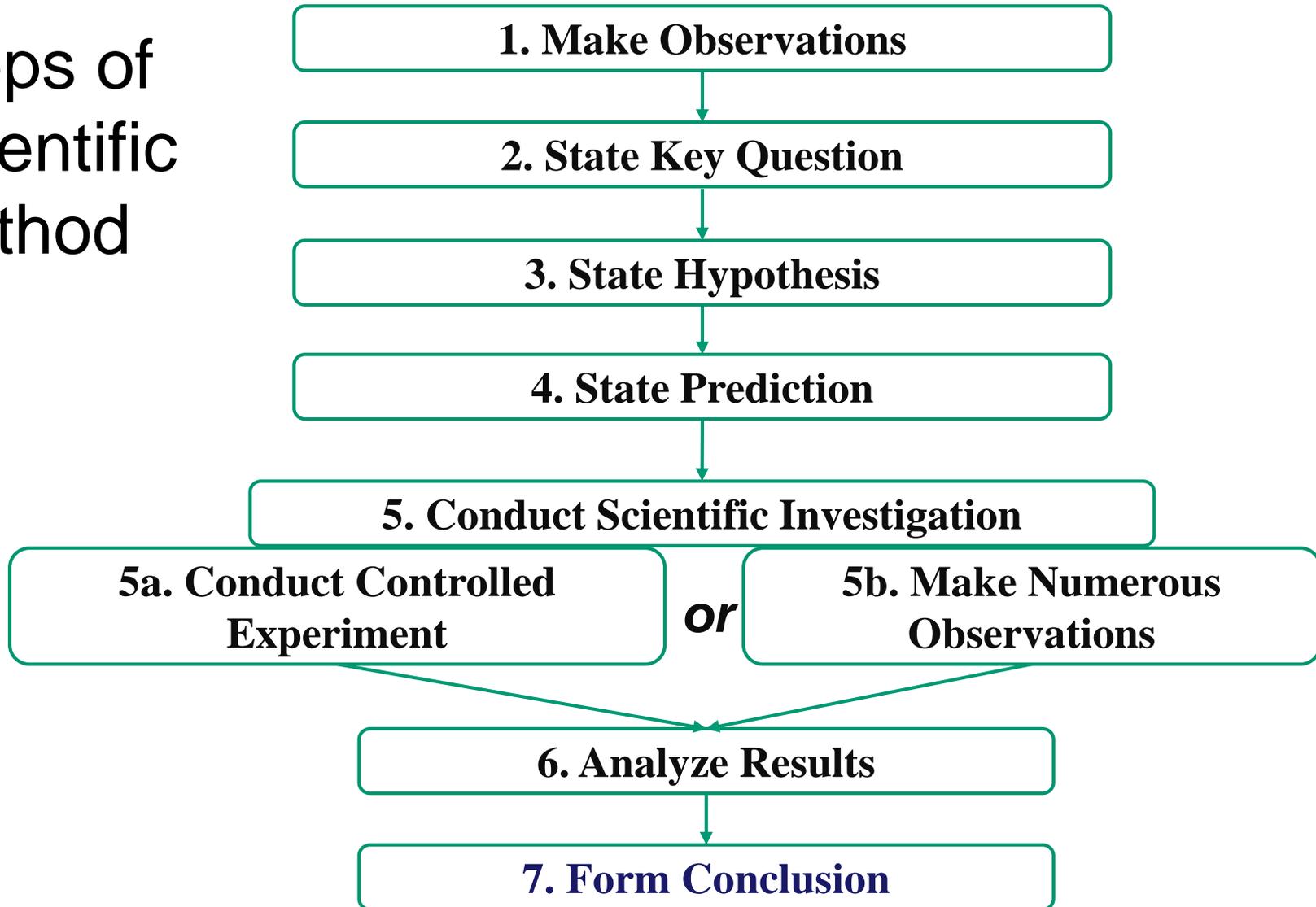
Dissect and microscopically examine many different animal tissues to see if they are composed of individual cells.

Steps of Scientific Method



Analyze and summarize data to facilitate interpretation of data

Steps of Scientific Method



If analyzed data support the prediction, the hypothesis is accepted and a scientific investigation is concluded; otherwise, the hypothesis is rejected and another scientific investigation is conducted with new hypothesis .

What's Next?

- If the hypothesis confirmed:
 - When supporting evidence keep accumulating, a hypothesis becomes theory:
 - “theory of relativity”
 - “theory of evolution”
 - With more evidence accumulated, a theory becomes a law:
 - “law of universal gravity”
 - “law of energy conservation”
- If the hypothesis rejected:
 - 1) Need to review to find out why
 - 2) Start over from observation
 - 3) Formulate a new hypothesis
 - 4) Carry out new controlled experiment
 - 5) Analyze and draw conclusion
 - 6) Repeat until acceptable answer is obtained

Often, the falsification of a hypothesis can provide more information than confirmation, since the ideas and data must be critically evaluated in light of new information.

Controlled Experiment vs. Numerous Observations

- Controlled Experiment:
Test affecting factors

Example: test the effect of fertilizer

- Numerous Observations:
Involves untestable factors

*Example: see if all organisms are
composed of cells*

Q 1-2. *In our example, which method would be most appropriate to test the hypothesis: “Fertilization promotes the growth of plants”; controlled experiments or multiple observations?*

Controlled experiment

(We can manipulate amount of fertilizer and measure the growth of plants)

Q 1-3. *Do you think the generalization that all organisms are composed of cells was established using controlled experiments or multiple observations?*

Multiple observations

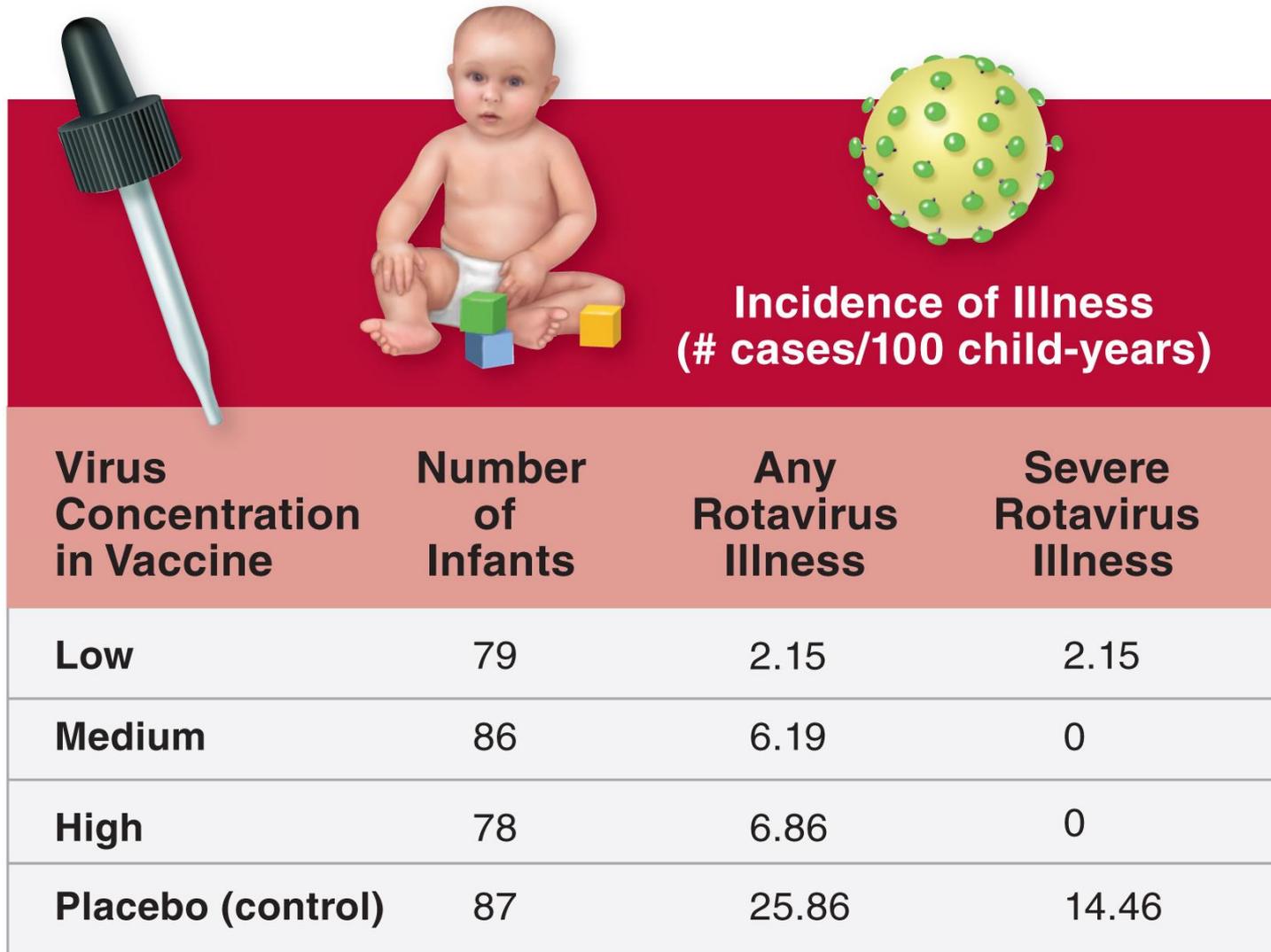
(Scientists made numerous observations and came to the generalization.)

- Three variables in a controlled experiment:
 - **Independent**: condition that is being evaluated for its effect on the *dependent variable* (in our example, addition of fertilizer) – **changed/manipulated by investigator**
 - **Dependent**: measured effect caused by changes of condition in independent variable (heights of plants) – **measured by investigator**
 - **Controlled**: all other conditions that could affect the independent variable (heights of plant):
The factors (such as temperature, humidity, any other factors) that can affect the growth of plant must be kept constant. Otherwise, we can tell the increase in plant heights is solely due to fertilization. – **kept constant/unchanged**
- There are 2 groups of treatments:
 - **Controlled group**: does not receive treatment
 - **Experimental group**: receive treatment

Controls:

- What is the significance of having a control?
 - Gives a basis of comparison
- What is a way to remove bias from an experiment?
 - Double Blind Test
- What is the placebo effect? Is there any significant evidence to support placebos?
 - Often used in medical studies to test effectiveness of new drug.

In this experiment, a test of new vaccine against the flu was tested. What is the Independent Variable? Dependent Variable? Control group? Was the vaccine effective?



1. *For each of the following examples, describe an appropriate control treatment.*

1a. *An investigator studies the amount of alcohol produced by yeast when it is incubated with different types of sugars.*

Dep.Var.= Amt. of alcohol produced

Control treatment: **Indep.Var. = Types of sugar** —

Control = No sugar

1b. *An investigator measures the effect of light intensity on photosynthesis by collecting oxygen produced by a plant.*

Dep.Var.= Amt. of oxygen produced

Control treatment: **Indep.Var. = Light intensity** —

Control = No light (darkness)

- 2. Why is it necessary to divide the plants into two groups (a control group and an experimental group)?*

If we have only the experimental group, we would have no way of knowing whether the increased growth is due to fertilization or the weather, water, etc. The control group provides us with the basis to make comparisons.

- 3. Why is it important to keep conditions exactly the same in the control and experimental groups, except for the application of fertilizer?*

As there are many factors that can affect the growth of plants, we need to keep the condition exactly same, except for the factor we are testing (e.g. fertilization). If the two groups of plants showed different growth rates under the same condition, we can tell it was caused by fertilization.

- **Yes. Experimental plants grew taller.**

1. Were there differences in growth between the control and experimental plants? If so, which group grew taller?
 - **Yes. Plants in the experimental group (fertilized) grew taller in average height than those in control group (non-fertilized).**
2. What is your conclusion? Do the results support the original hypothesis? Explain your answer.
 - **When Plants are fertilized, they grow taller. Yes, the results support the original hypothesis. *The added fertilizer made plant grow taller.***
3. Why is it more accurate to compare the average height gain of the control and experimental groups (instead of comparing individual plants)?
 - **By comparing the average height gains, we can reduce the effect of variability among individual plants, such as genetic variability.**

Simplest ways to summarize the data

- Mean (average) : sum of measurement/number of samples
- Mode: most frequently occurring value
- Median: middle number when arranged in order (when 2 values are in the middle, take average of the two)
- Range: difference between smallest and largest measurements

Q 3-3. In the following set of numbers, what is the mode? 38

3, 25, 29, 38, 38, 38, 39, 40, 40, 100

Q 3-4. In the following set of numbers, what is the median? 38

3, 25, 29, 38, 38, 38, 39, 40, 40, 100

1 2 3 4 5 6 7 8
9 10

$$(38 + 38) / 2 = 38$$

Q 3-5. In the following set of numbers, what is the range? 97

3, 25, 29, 38, 38, 38, 39, 40, 40, 100

$$100 - 3 = 97$$

1. *What's the range of exam scores in Table 3-3?*

Student Number	Exam Score1	Student Number	Exam Score 1
1	90	11	88
2	94	12	54
3	80	13	32
4	82	14	47
5	91	15	25
6	46	16	56
7	97	17	59
8	96	18	60
9	87	19	87
10	84	20	86

$$\text{Range} = 97 - 25 = 72$$

To find a median, arrange in ascending order of exam score

2. *If your exam score was 80, was your score in the top 50% of the class?*

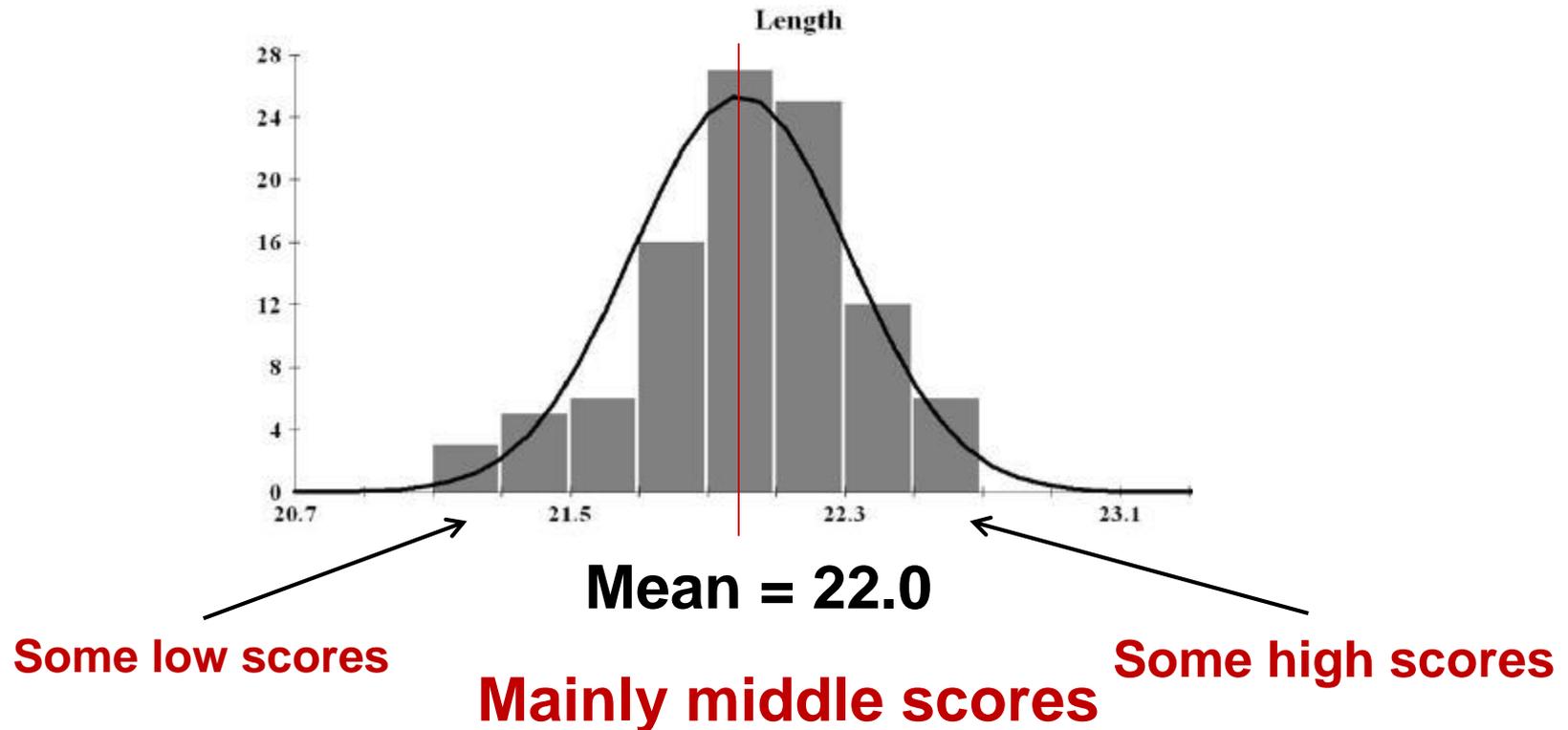
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5	91	15	25
6	46	16	56
7	97	17	59
8	96	18	60
9	87	19	87
10	84	20	86

Student	Score	Order
15	25	1
13	32	2
6	46	3
14	47	4
12	54	5
16	56	6
17	59	7
18	60	8
3	80	9
4	82	10
10	84	11
20	86	12
9	87	13
19	87	14
11	88	15
1	90	16
5	91	17
2	94	18
8	96	19
7	97	20

**The middle number (Median) = $(82+84)/2=83$
Thus score 80 is lower than top 50%**

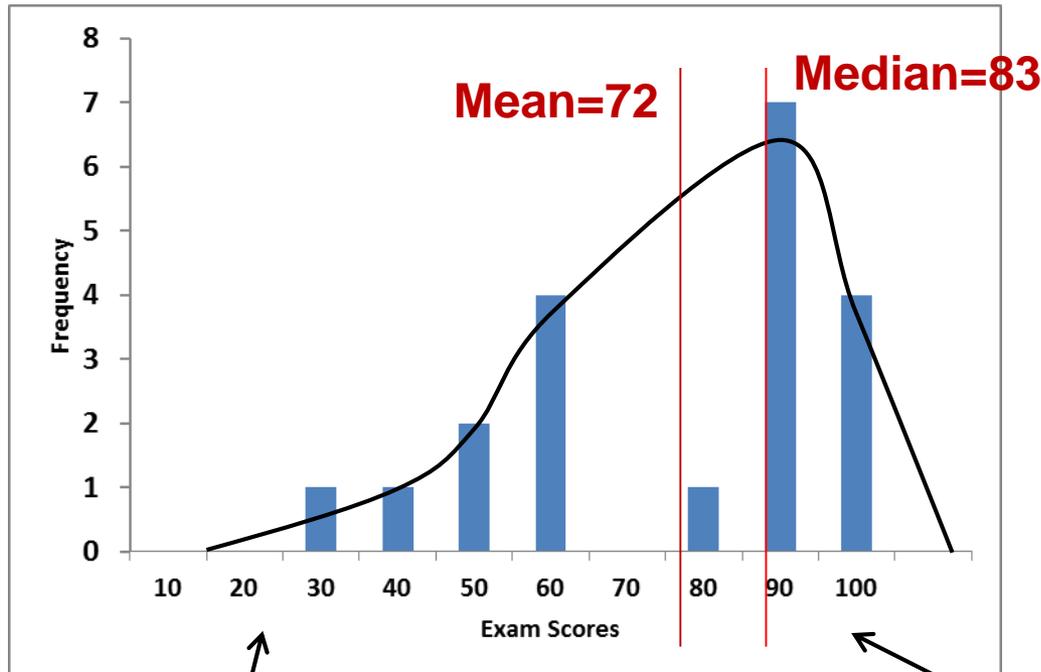
In this situation, is the mean a good representation of the class scores? Why or why not?

As a general rule, when a data set has normal distribution (symmetrical bell shape) mean is a good representation of the data.



When a data set has skewed distribution (non-symmetrical bell shape) median is a good representation of the data.

Student	Score	Order
15	25	1
13	32	2
6	46	3
14	47	4
12	54	5
16	56	6
17	59	7
18	60	8
3	80	9
4	82	10
10	84	11
20	86	12
9	87	13
19	87	14
11	88	15
1	90	16
5	91	17
2	94	18
8	96	19
7	97	20



Some low scores

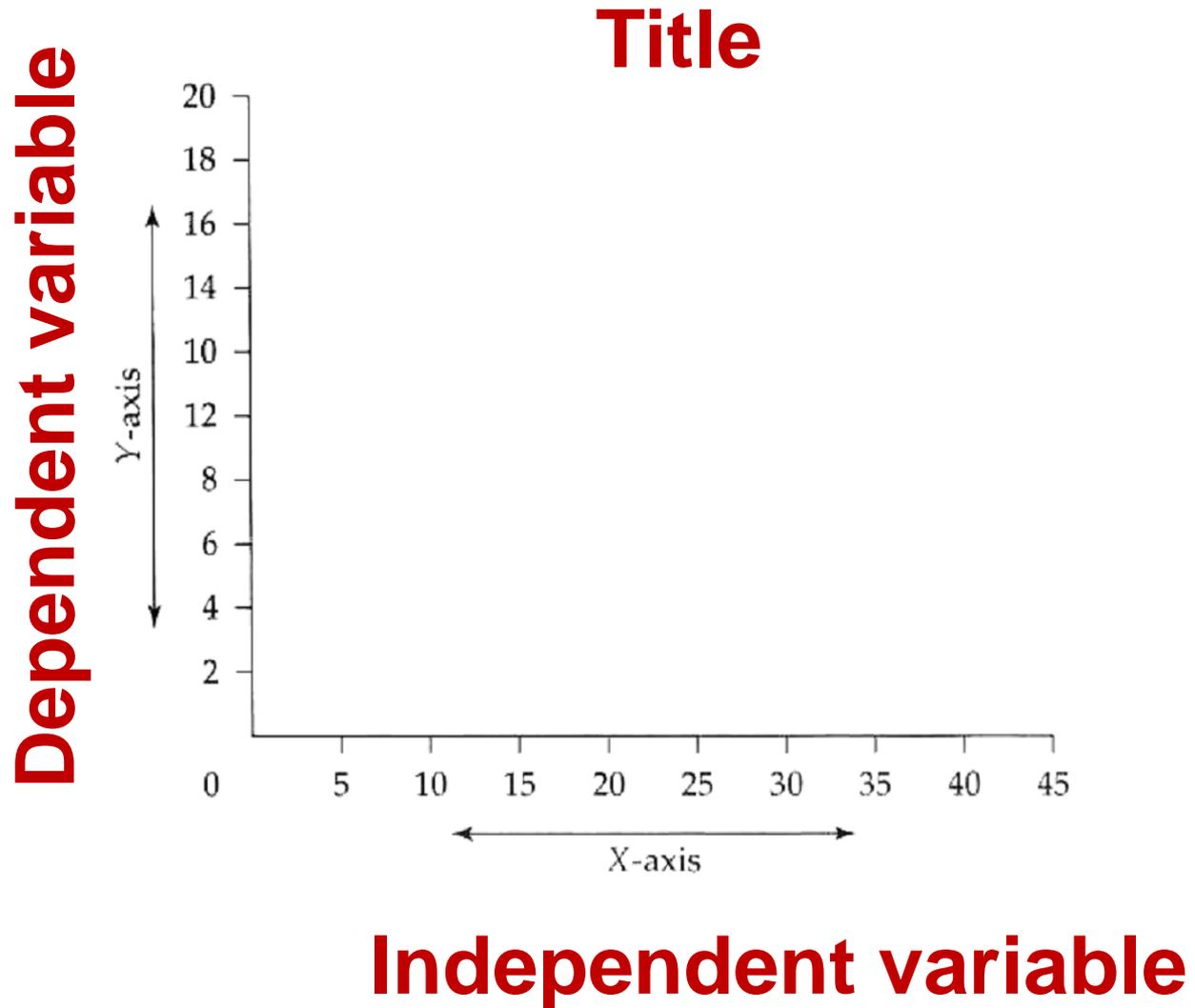
Many middle and high scores

- However, choice of mean or median “*depends*” on the purpose of your data analysis.
 1. If you are interested in what the mid range of exam score, median is more appropriate. → You won’ t know the total exam score of the class.
 2. If you want see overall performance of a class or compare it to another, mean is appropriate as you can know the total (= mean x number of students).
 3. If you have ‘outliers’ , which are very different from majority; for example,

2, 5, 67, 75, 81, 90, 99

First to values drastically affect the mean (60), and median (75) is more representative for this set of values.

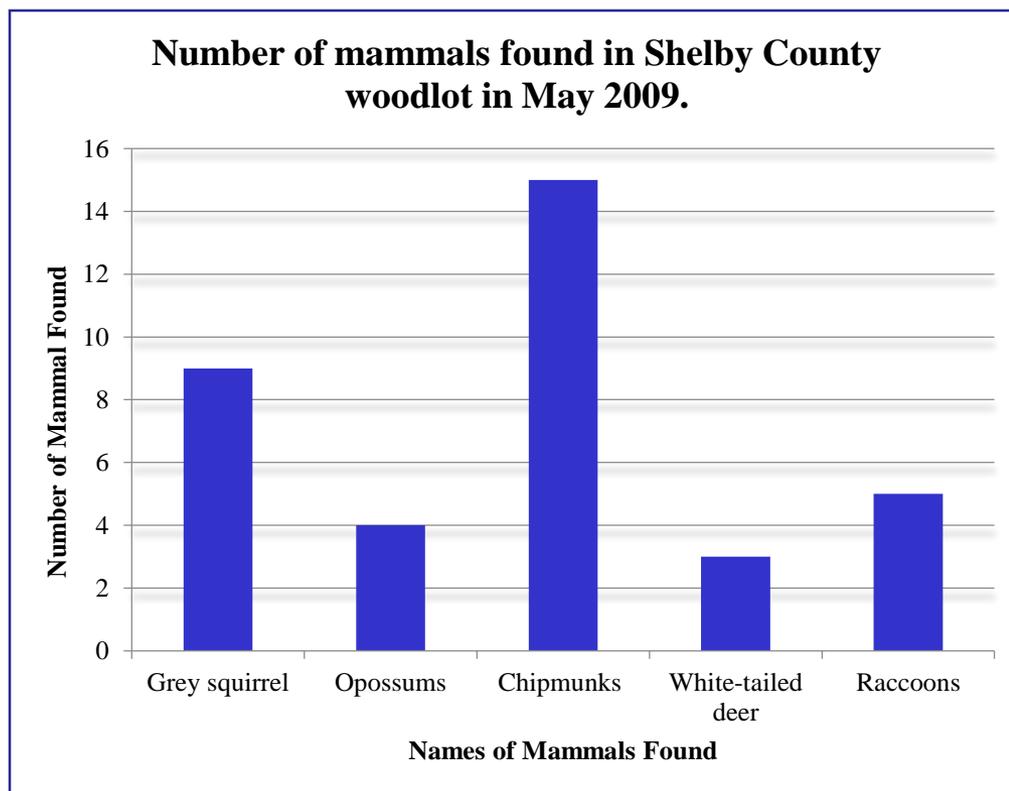
Graphing Data



Bar graphs: best when the data are in groups or categories.

Example: population counts of several different kinds of mammals in a woodlot in Shelby County, TN in May 2009.

Grey squirrel	9
Opossums	4
Chipmunks	15
White-tailed deer	3
Raccoons	5

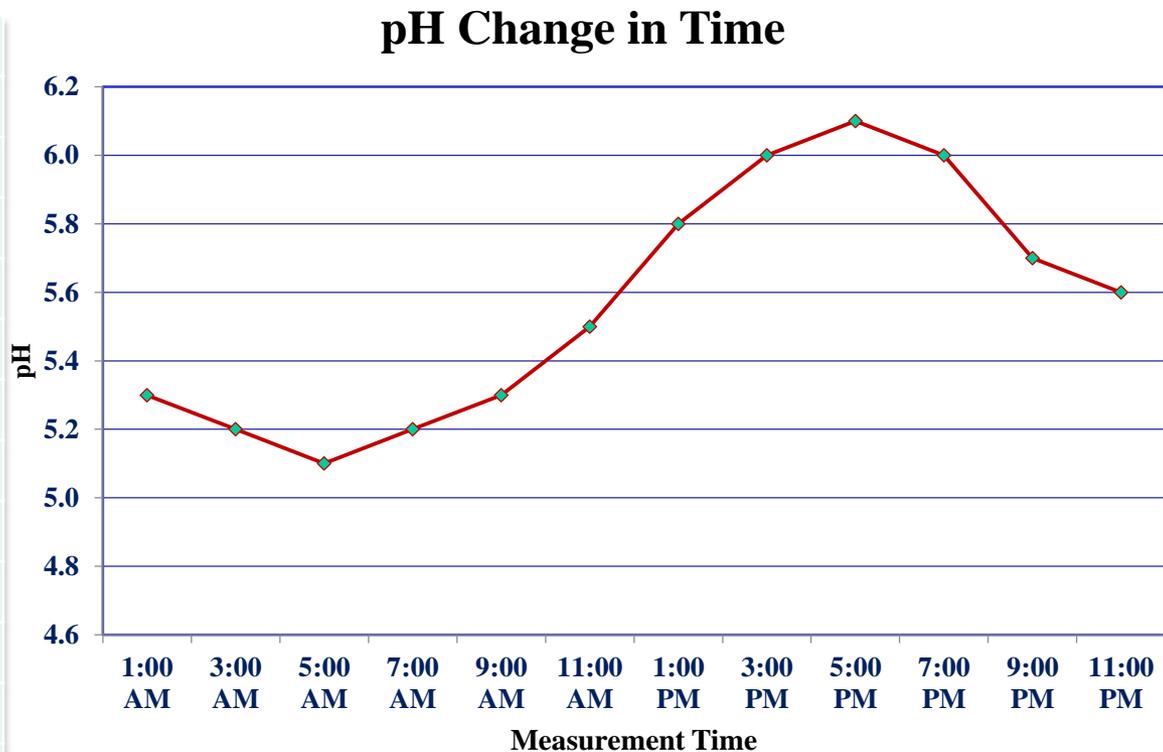


A bar graph is best for these data because they are categories or discrete; it is not possible to have a data point that is between grey squirrels and opossums.

Line graphs: Best when the data are continuous.

Example: pH measurements of a pond between 1:00 AM and 11:00 PM

Measurement	Time pH
1:00 AM	5.3
3:00 AM	5.2
5:00 AM	5.1
7:00 AM	5.2
9:00 AM	5.3
11:00 AM	5.5
1:00 PM	5.8
3:00 PM	6
5:00 PM	6.1
7:00 PM	6
9:00 PM	5.7
11:00 PM	5.6



A line graph is appropriate because the data are continuous. In this line graph, the pH at 2:00 AM can be estimated, although it was not actually measured.

Theories are Comprehensive Explanations

- Outside of science, the word **theory** is often used to describe a hunch/opinion.
- In science, **theory** is an explanation for a natural phenomenon after extensive experimental evidence
- Theories differ from hypotheses in 3 ways:
 1. Theories are broader in scope than hypotheses
 2. Theories are more broadly accepted
 3. Theories have more predicting power

Scientific Inquiry Has Limitations

- Scientific inquiry is not foolproof or always easy to implement.
- One problem is that experiment evidence can have multiple interpretations, and even the most carefully designed experiments do not always answer the initial question definitively.
- Another problem is researchers can misinterpret observations or results as seen in spontaneous generations, instead did not understand anaerobic bacteria
- A related problem is that the scientific community and/or general public may be slow to accept conclusions that go against what we initially thought or traditional view points

Lets bring it home!!!

1. What are the steps in the scientific method?
2. Can you identify the independent, dependent variable?
Control?
3. Do you understand simple experimental design?
4. What is the difference between a hypothesis and a theory?
5. What are some limitations of scientific inquiry?
6. How can data misinterpretations misguide the public?

Pass out Saccharin Scare

Table 1.A Tumors in Two Generations of Rats

Rats with Tumors/Rats Examined (% with tumors)		
	Parents	Offspring
Male rats		
Saccharin-fed	7/38 (19%)	12/45 (27%)
Controls	1/36 (3%)	0/42 (0%)
Female rats		
Saccharin-fed	0/40 (0%)	2/49 (4%)
Controls	0/38 (0%)	0/47 (0%)

Pull it all together

