Introductory Zoology

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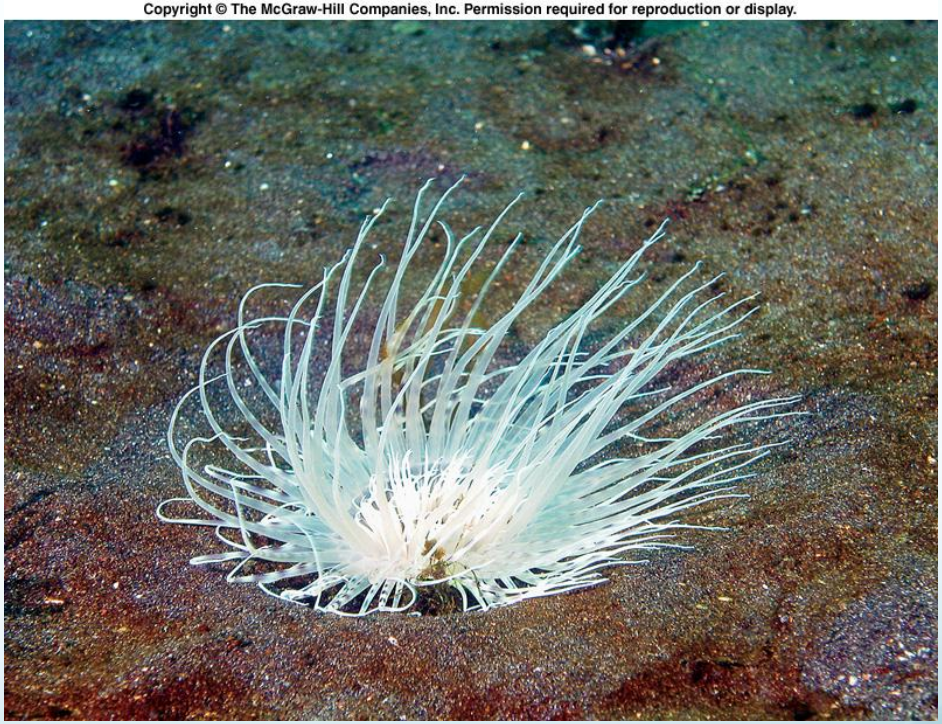
The Science of Zoology

- **Zoology** is the study of *animal* life.
- Zoologists strive to understand:
  - The origin of animal diversity.
  - How animals perform basic life processes.
  - How they are able to inhabit various ecosystems.



The Uses of Principles

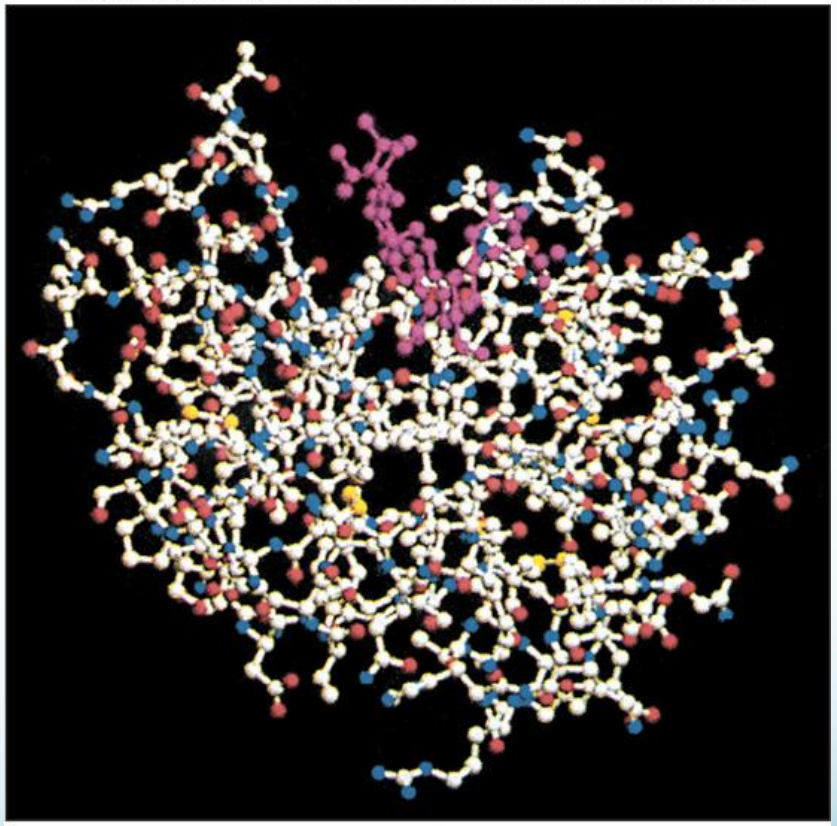
- Principles of modern zoology are derived from:
  - Laws of physics and chemistry
  - Scientific method
- Because life shares a common evolutionary origin, principles learned from the study of one group often pertain to other groups as well.

Properties of Life

- Does Life Have Defining Properties?
  - What is life?
    - No simple definition.
    - The history of life shows extensive and ongoing change called **evolution.**
    - Answer must be based on the **common history** of life on earth.

Properties of Life

1. **Chemical Uniqueness** – Living systems demonstrate a unique and complex molecular organization.



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Chemical Uniqueness

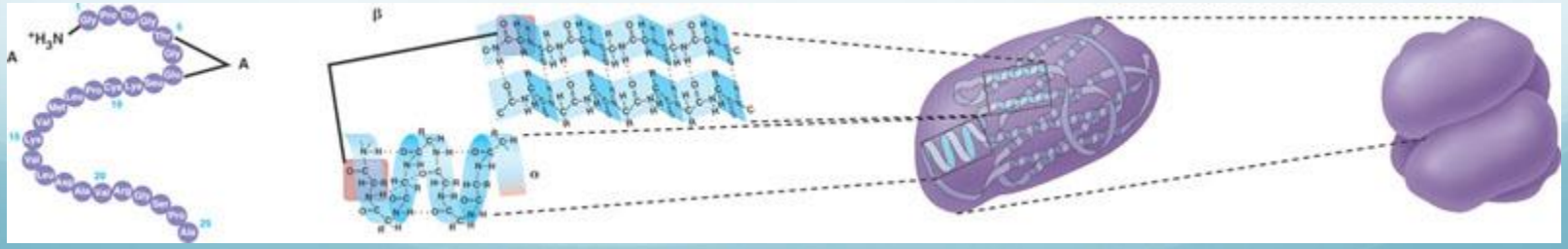
- Living organisms assemble large molecules – **macromolecules** – that are more complex than molecules found in nonliving matter.
  - Same chemical laws apply.
  - Four categories of biological macromolecules:
    - **Nucleic acids**
    - **Proteins**
    - **Carbohydrates**
    - **Lipids**

Chemical Uniqueness

- These 4 groups differ in their:
  - Components
  - Types of bonds holding them together
  - Functions
- Macromolecules evolved early in the history of life.
- Found in every form of life today.

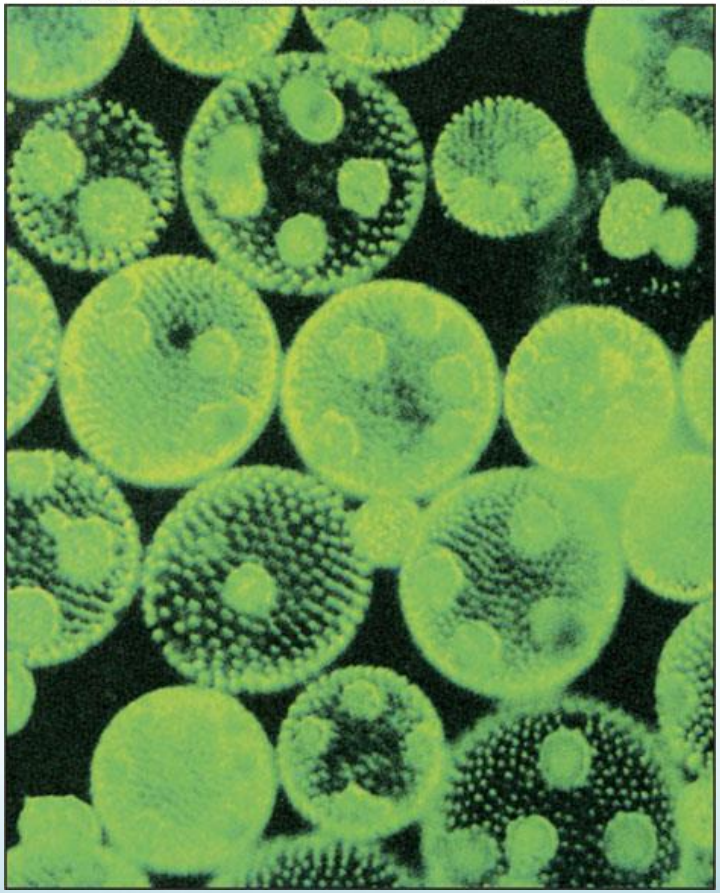
Chemical Uniqueness

- **Proteins** are made up of 20 different amino acid subunits.
- Enormous variability allows for the diversity of proteins and consequently of living forms.
- **Nucleic acids**, **carbohydrates** & **lipids** are also organized in a way that gives living systems a large potential for diversity.



Properties of Life

2. **Complexity and Hierarchical Organization** – Molecules are organized into patterns in the living world that do not exist in the nonliving world.

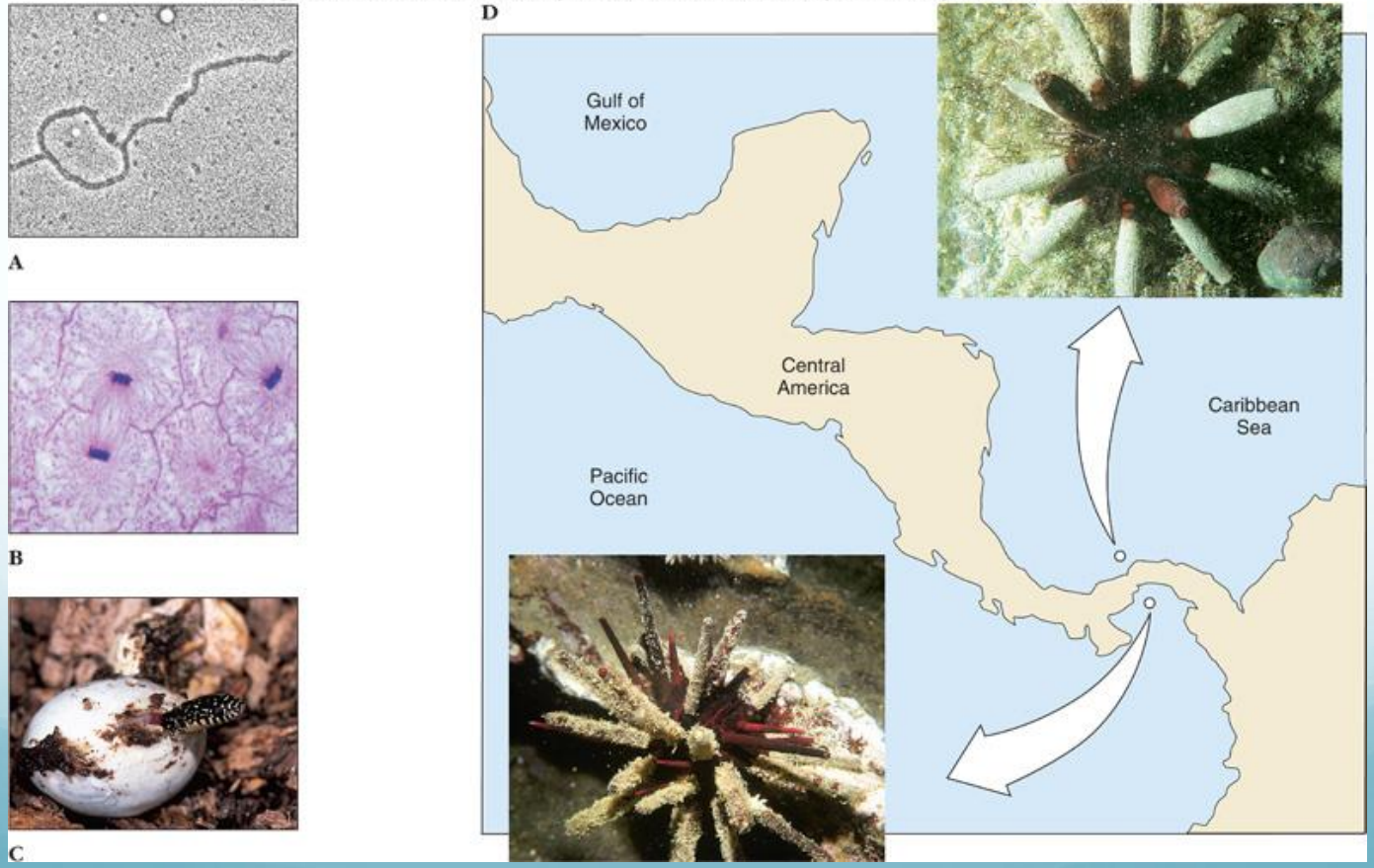


Complexity and Hierarchical Organization

- New characteristics can appear at any level of organization – **emergent properties**.
- Emergent properties depend upon the characteristics found at lower hierarchical levels – to some extent.
  - The development of spoken language requires hearing.
  - But, many different languages have arisen.

Properties of Life

3. **Reproduction** – Living systems can reproduce themselves!



Reproduction

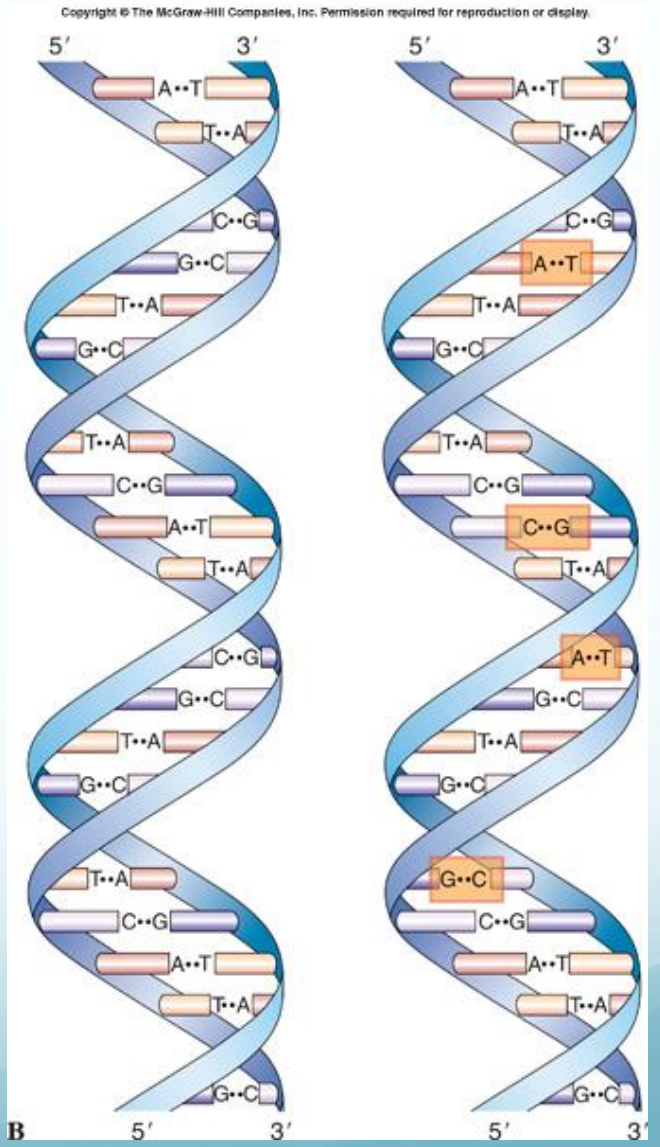
- Genes replicate themselves forming new genes.
- Cells divide to produce new cells.
- Organisms reproduce to produce new organisms.
- Populations can split to form new populations.
- Even species may split to produce new species - **speciation**.

Reproduction

- Heredity and variation are present at all of these levels.
  - **Heredity** – faithful transmission of traits from one generation to the next.
  - **Variation** – production of differences among the traits of individuals.
- Result: offspring are similar to – but not exactly like parents.

Properties of Life

4. **Genetic program** – provides fidelity of inheritance.

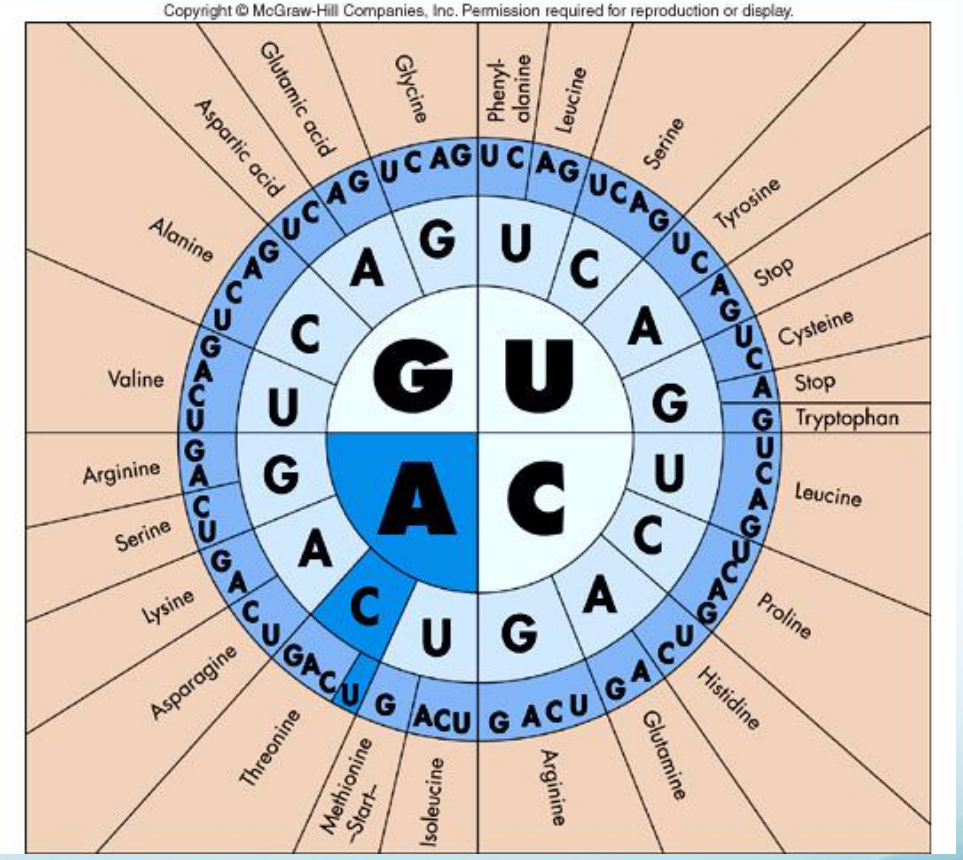


Genetic Program

- Genetic information is coded in **DNA**.
- DNA is a long chain of **nucleotides** – a sugar, phosphate + nitrogenous base (A, C, G, & T).
  - The sequence of nucleotides codes for the order of amino acids in the protein specified.
    - The **genetic code**

Genetic Program

- The genetic code is ***universal*** among living organisms from bacteria through humans.
  - Supports the concept of a single origin of life.



Properties of Life

5. **Metabolism** – Living organisms maintain themselves by acquiring nutrients from their environments.

A

B

Metabolism

- **Metabolism** includes all of the chemical reactions occurring within an organism.
  - Digestion
  - Respiration
  - Synthesis of molecules and structures

Metabolism

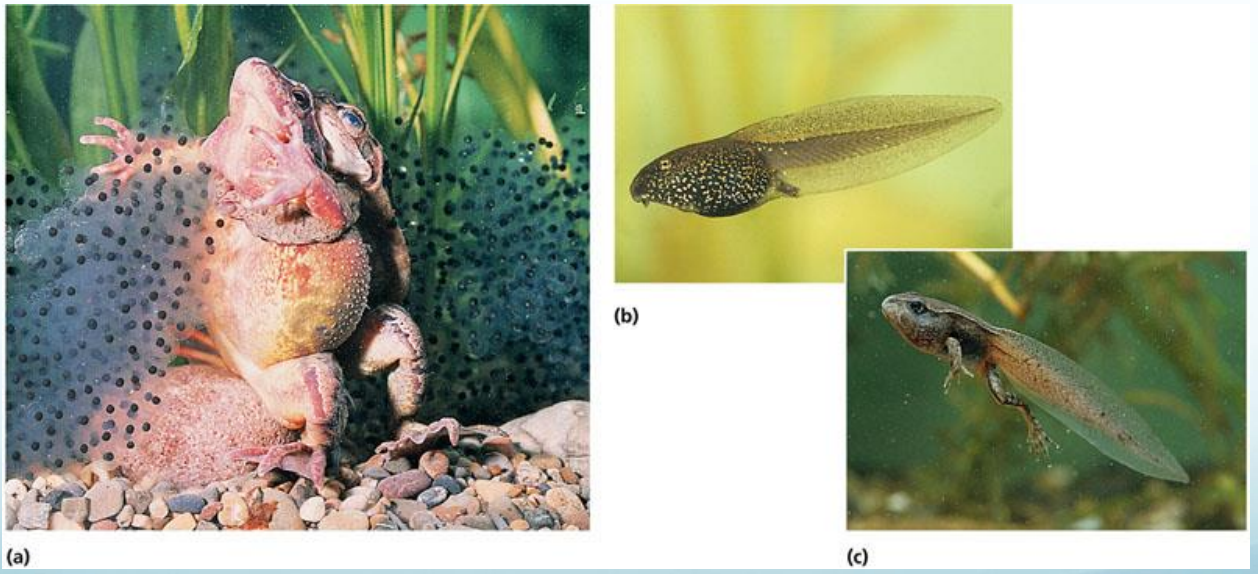
- Metabolism includes destructive (**catabolic**) and constructive (**anabolic**) reactions.
- These reactions include synthesis of the 4 types of macromolecules as well as cleavage of bonds to recover the energy stored there.
- **Physiology** – the study of complex metabolic functions.

Properties of Life

6. **Development** – All organisms pass through characteristic stages in their life cycle.

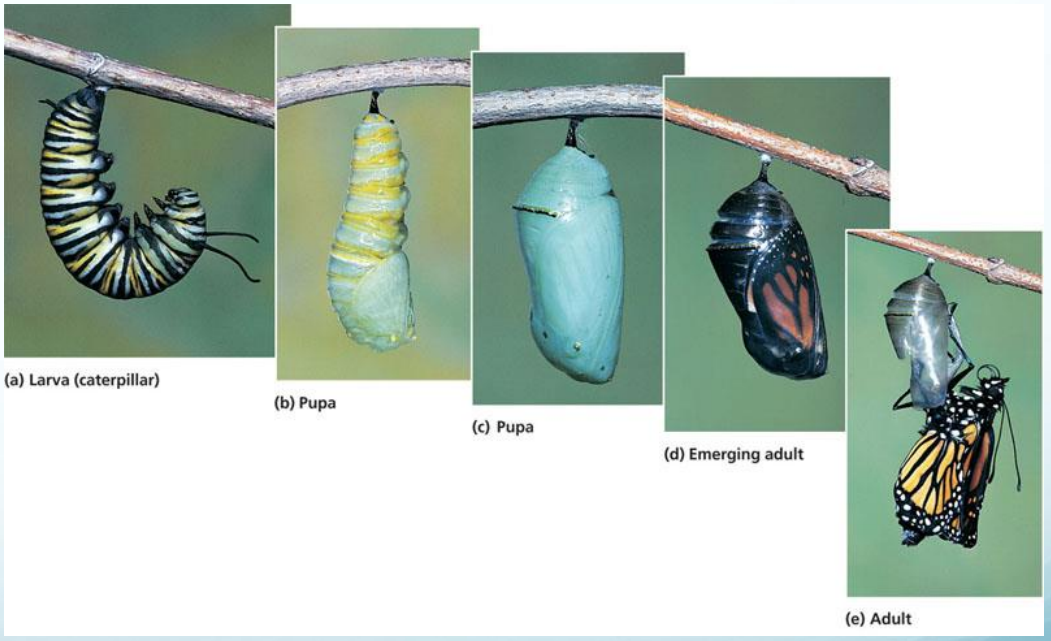
Development

- Development includes characteristic changes an organism passes through from its beginning (usually as a fertilized egg) through adulthood.



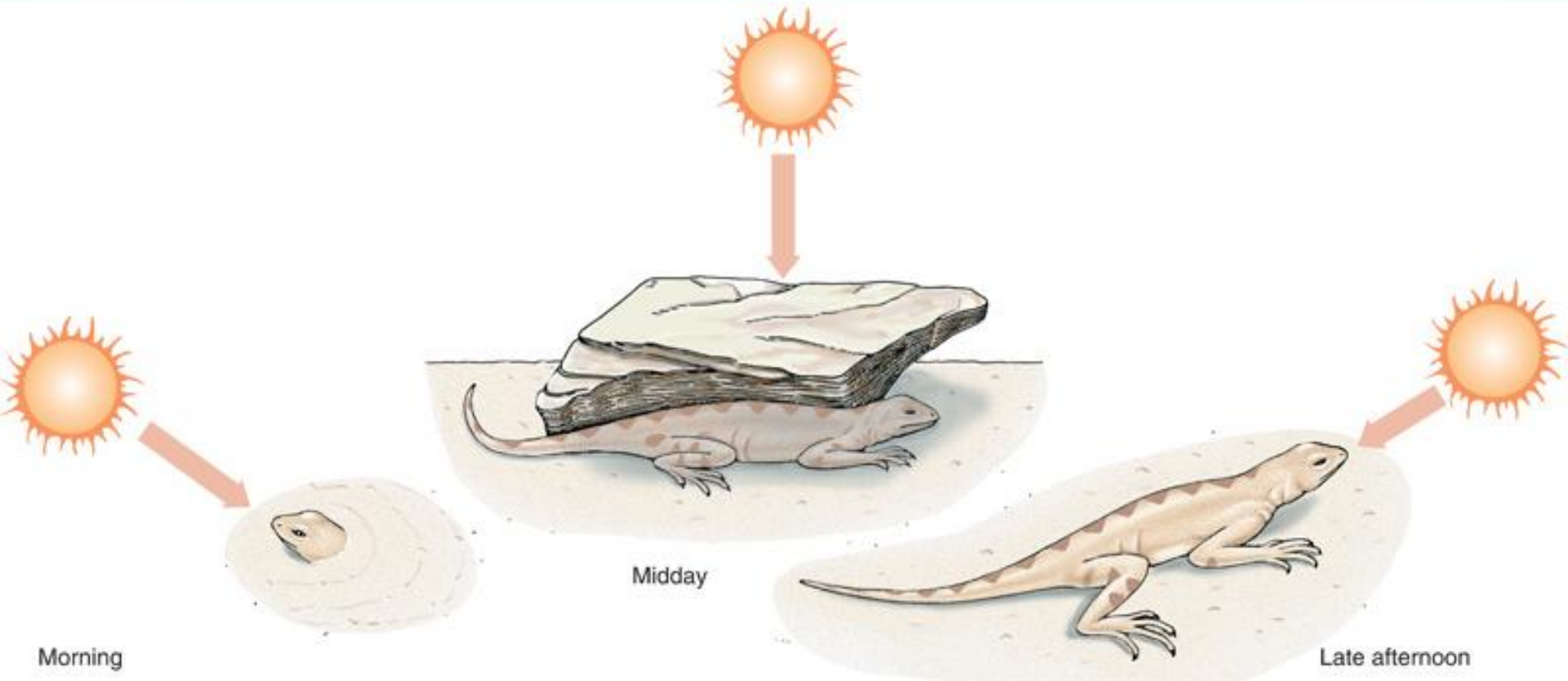
Development

- **Metamorphosis –** transformation from one life stage to another.
  - Tadpole to frog
  - Caterpillar to butterfly



Properties of Life

7. **Environmental interaction** – Living organisms interact with their environments.



Environmental Interaction

- **Ecology** is the study of this interaction between organisms and between organisms and their environment.

Properties of Life

8. **Movement** – Living systems and their parts show precise and controlled movements arising from within the system.

   - Living systems extract energy from their environments permitting the initiation of controlled movements.

Movement

- Movements at the cellular level are required for:
  - Reproduction
  - Growth
  - Responses to stimuli
  - Development in multicellular organisms

Movement

- On a larger scale:
  - Entire populations or species may disperse from one geographic location to another over time.
- Movement of nonliving matter:
  - Not precisely controlled by the moving objects.
  - Often involves external forces.

Physical Laws

- **First Law of Thermodynamics** – Energy can not be created or destroyed, but can be transformed.
  - Energy enters our system as sunlight. The energy in the sunlight is transformed into chemical bonds through **photosynthesis**.
  - When these bonds are broken, the energy is released.

Physical Laws

- **Second Law of Thermodynamics** – Physical systems proceed toward a state of **entropy** or disorder.
  - Energy is required to maintain the complex organization in living organisms.

Physical Laws

- The complex molecular organization in living cells is attained and maintained only as long as energy fuels the organization.
- Survival, growth, and reproduction of animals require energy that comes from breaking complex food molecules into simple organic waste.

Zoology As Part of Biology

- **Biology** is the study of living organisms.
- **Zoology** focuses on the Kingdom Animalia.
  - In this course we'll be studying the diversity of animals on our planet, how they are related, how they work, and how they interact with each other.

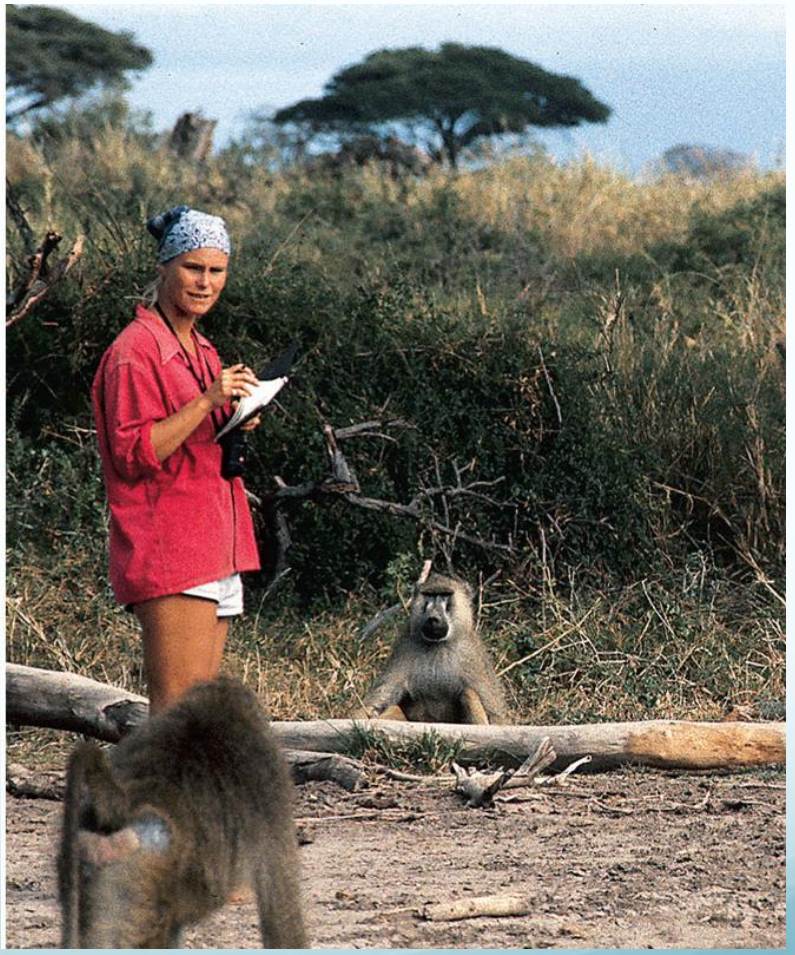
Zoology As Part of Biology

- Animals originated in the Precambrian seas over 600 million years ago.
- Characteristics of Animals:
  - **Eukaryotes**: cells contain membrane-enclosed nuclei.
  - **Heterotrophs**: Not capable of manufacturing their own food and must rely on external food sources.
  - **Cells lack cell walls**

The Nature of Science

The Nature of Science

- Science is a way of asking questions about the natural world.
  - Guided by natural laws (physical & chemical).
  - Questions must be **testable**!
  - Always open to new evidence.
  - **Falsifiable**.



Experimental and Evolutionary Sciences

- We can ask different types of questions about animals.
  - Questions about **proximate** (or immediate) causes.
  - Questions about **ultimate** causes.

Proximate Cause

- Questions about the **proximate** (or immediate) causes that underlie the functioning of a biological system can be studied using the "scientific method".
  - How does an animal perform its metabolic, physiological or behavioral functions?
    - Molecular biology
    - Cell biology
    - Endocrinology
    - Developmental biology
    - Community ecology

Scientific Method

- First is the **observation** phase, where new observations are made.
  - This is also the time where previous data are examined.
- Next, a **hypothesis** is formulated to attempt to explain the available data and observations.
  - A hypothesis must be **testable**!!!

Principles of Science

- **Hypothesis**:
  - Potential answers to questions being asked.
  - Derived from prior observations of nature or from theories based on such observations.
  - Often constitute general statements about nature that may explain a large number of diverse observations.
  - If a hypothesis is very powerful in explaining a wide variety of related phenomena, it attains the level of a **theory.**

Scientific Method

- The hypothesis is then tested through a series of **experiments** and/or **observations**.
  - These experiments and observations must be **repeatable**!
  - The factual information resulting from these experiments and observations are called **data**.
  - An important part of an experiment is the **control**, which is a replicate set up exactly like the experiment, except it does not have the factor being tested.

Scientific Method

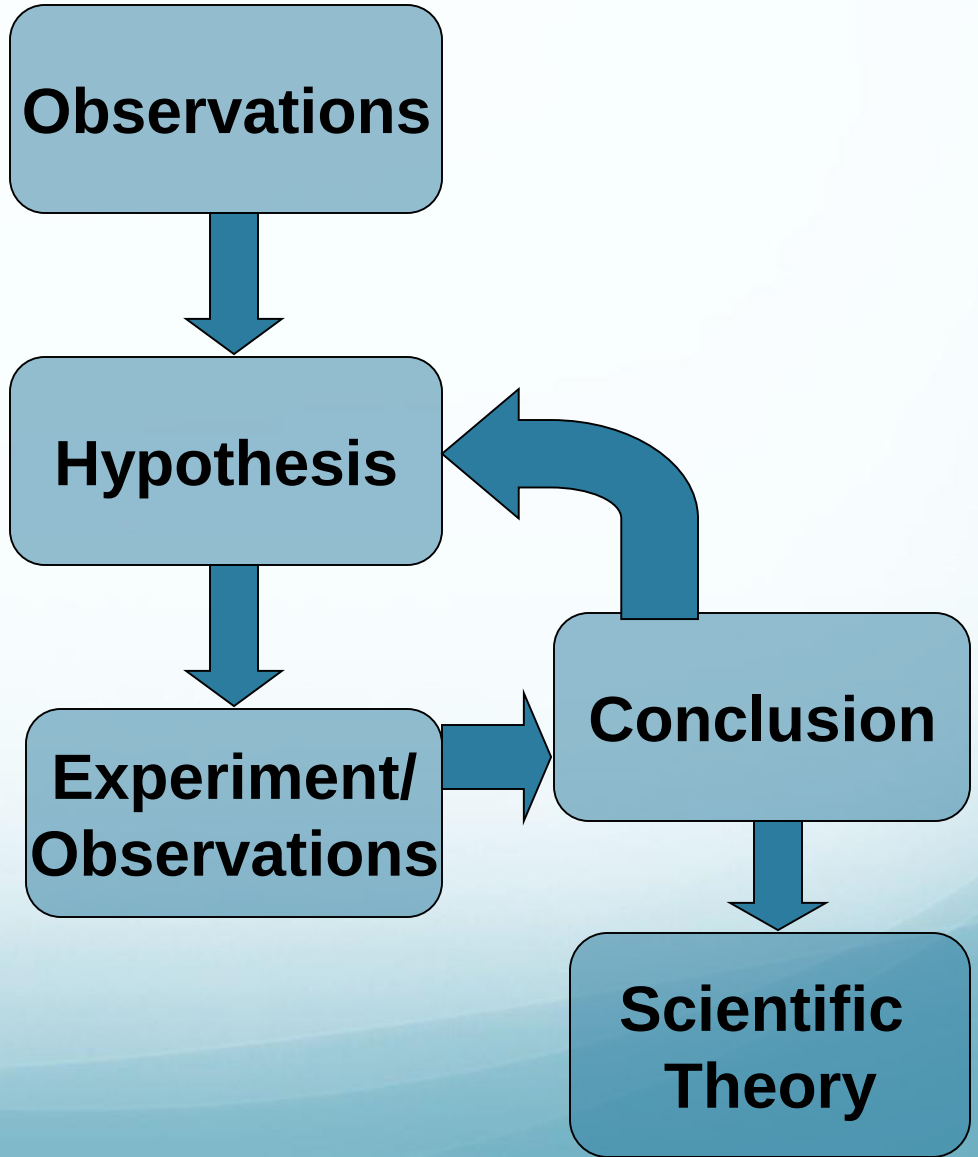
- Scientists can then draw a **conclusion** based on the data.
  - The conclusion may involve accepting or rejecting the initial hypothesis.
  - Further experiments may require an adjustment to the conclusions.
    - Hypotheses are said to be supported, ***but not proven***.

Scientific Method

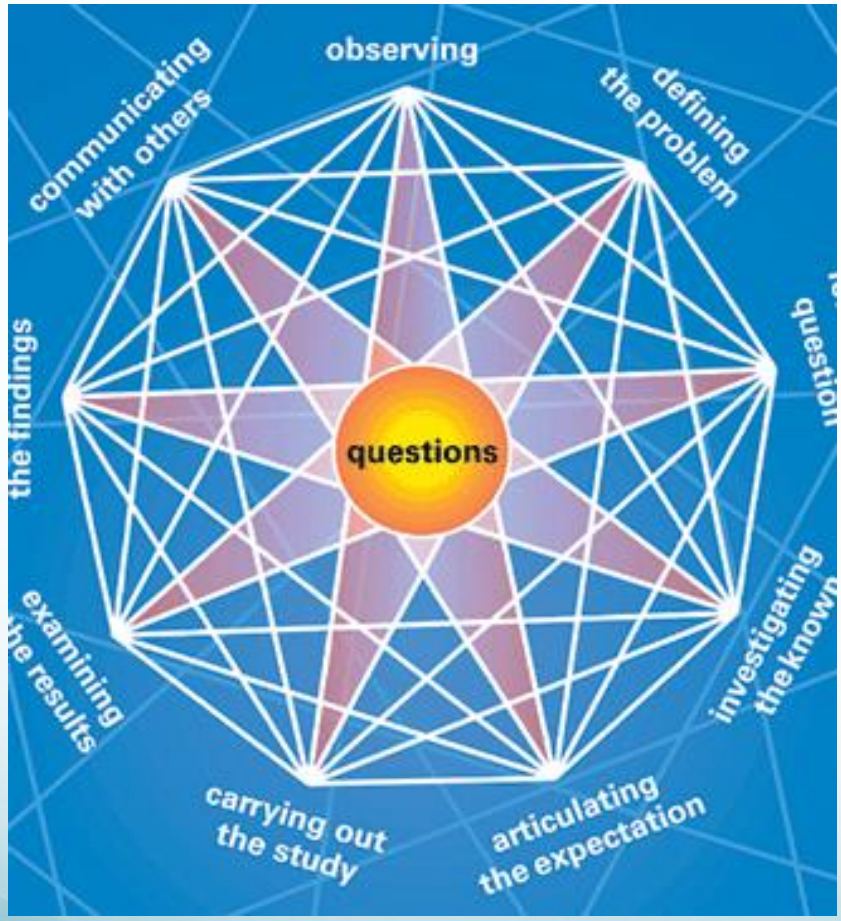
- New hypotheses are generated from the conclusions, and the process starts again.
- A **theory** results when a group of related hypotheses are supported by *many* experiments and observations.
  - Theories are the ideas that scientists are MOST SURE OF!
    - Theory of gravity
    - Theory of natural selection

Scientific Method

- This simplified flow diagram of the scientific method shows the important components involved in a scientific study.



Scientific Method



- The previous model is very simplified and the result is too linear.
- The '**activity model**' for the process of scientific inquiry shows the more complex interactions that are really involved.

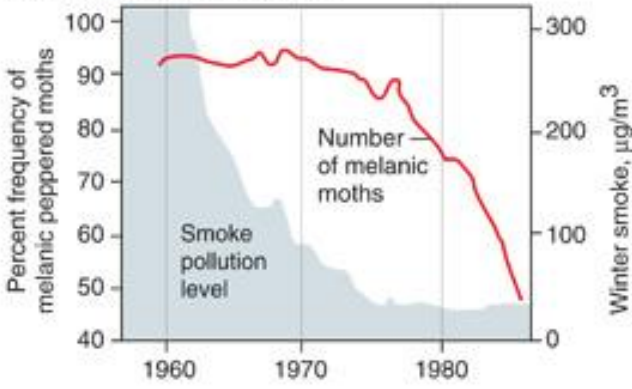
Harwood, W. S. 2004. A new Model for Inquiry: is the Scientific Method Dead? *Journal of College Science Teaching*. 33(7): 29-33.

Example Experiment

- Observation: Light moths more common in clean areas, dark moths more common in polluted areas.
- Prediction 1: Moths better able to survive if they match their background.
  - Supported by experimental studies with predatory birds.
- Prediction 2: If polluted areas are cleaned, light moths should become more common (as lichen grows on trees).

A

B



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Scientific Method

- "**Theory**," when used by scientists, is not just speculation as often implied by nonscientific usage.
- creationists, have called evolution "only a theory" to imply that it is little better than a random guess.
- In fact, evolutionary theory is supported by such massive evidence that most biologists view repudiation of evolution as tantamount to repudiation of reality.
- Nonetheless, evolution, like all other theories in science, is not proved by mathematical logic, but is testable, tentative, and falsifiable.

Ultimate Cause

- Some scientists ask questions about **ultimate** cause.
- The comparative method is used more than experimentation.
  - Comparative biochemistry
  - Molecular evolution
  - Comparative cell biology
  - Comparative anatomy
  - Comparative physiology
  - Phylogenetic systematics

Ultimate Cause

- In evolutionary biology, characteristics of molecular biology, cell biology, organismal structure, developmental biology and ecology are compared.
- Resulting patterns of similarity can be used to test hypotheses of relatedness.

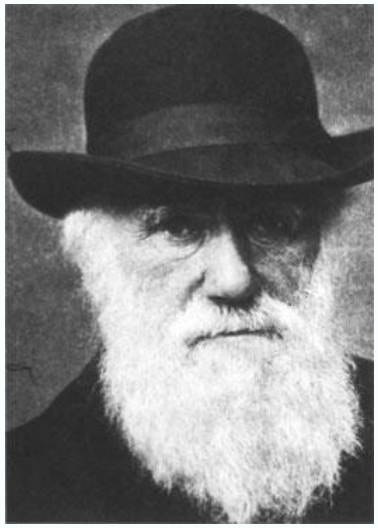
Evolution and Heredity

Evolution and Heredity

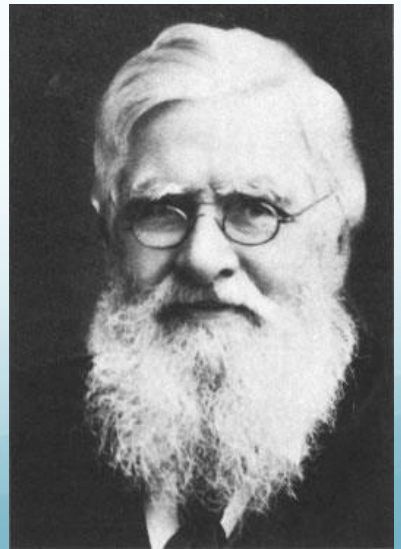
- Powerful theories that guide extensive research are called paradigms.
- The refutement and replacement of a paradigm is known as a scientific revolution.
- Two major paradigms that guide zoological research:
  1. Darwin's Theory of **Evolution**
  2. The Chromosomal Theory of **Inheritance**

Theory of Evolution

- **Charles Darwin** – *On the Origin of Species by Means of Natural Selection*, 1859.



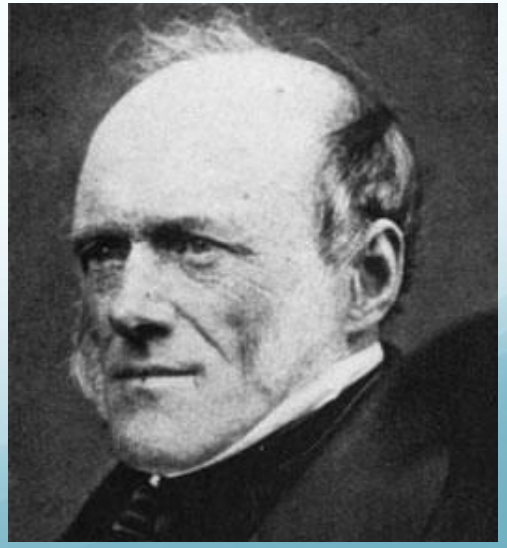
- **Alfred Russel Wallace**
- developed theory of natural selection independently



Influences on Darwin

- Lamark
  - first scientific explanation of evolution
  - “inheritance of acquired characteristics”
  - made case that fossils are remains of extinct animals

- Lyell
  - uniformitarianism—same physical laws & geological processes operate now as during Earth’s history

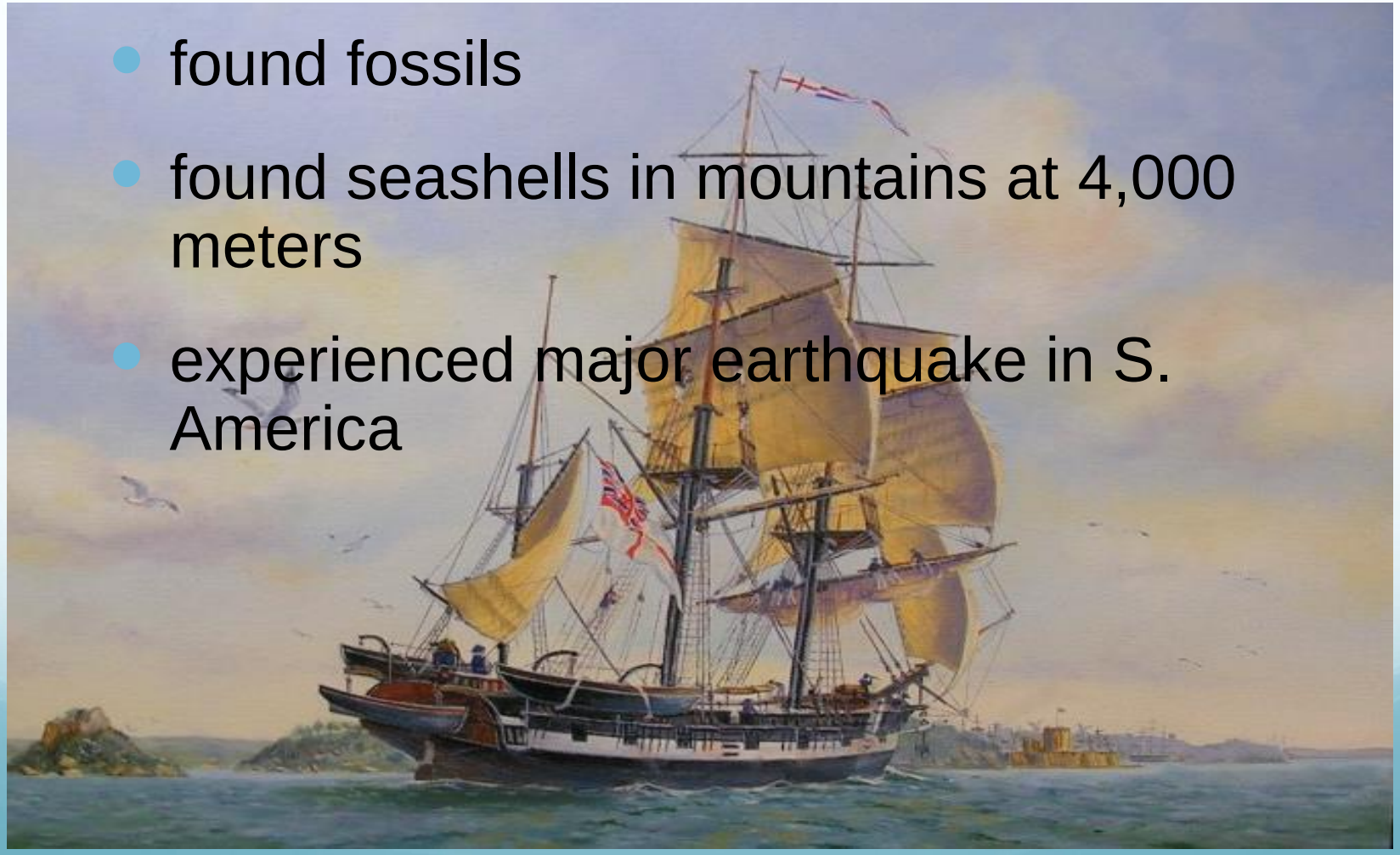


History of Evolution

- voyage of the H.M.S. *Beagle*
- Darwin 23 years old
- 5-year voyage around the world

History of Evolution

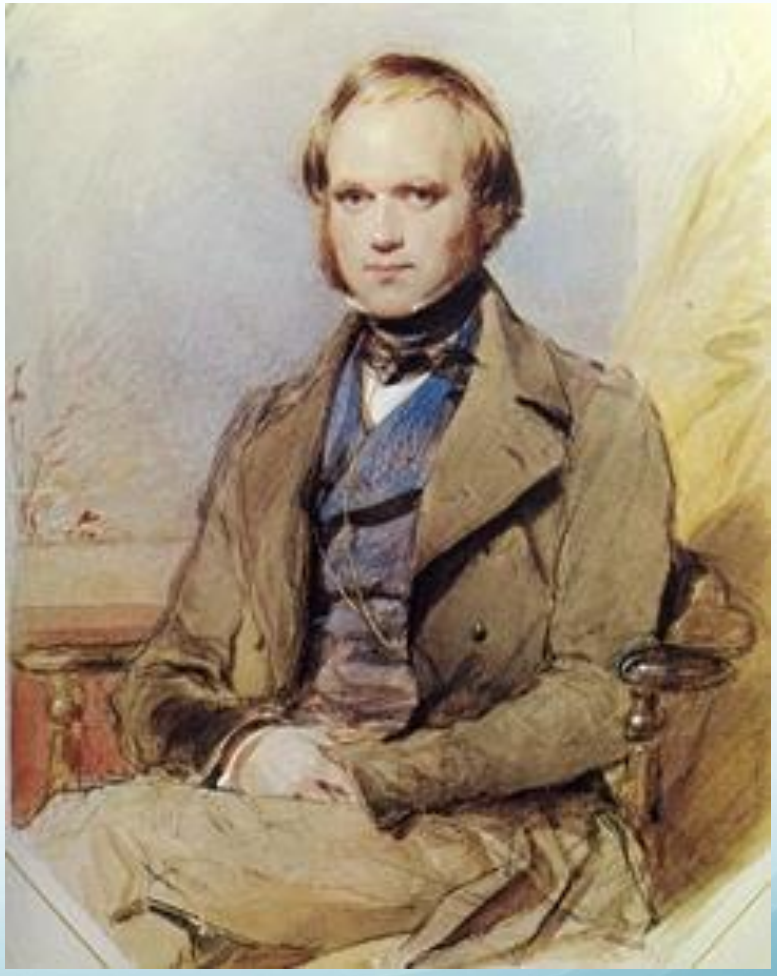
- observed & collected fauna & flora
- found fossils
- found seashells in mountains at 4,000 meters
- experienced major earthquake in S. America



History of Evolution

- *Beagle* stopped at the Galapagos Islands (on equator 600 miles off of W coast of S. America)

- spent 5 weeks on islands



History of Evolution

- Galapagos visit hugely influential on Darwin's development of theory of evolution
- organisms unique, yet similar to continental forms in S. America (e.g., giant tortoises due to lack of predators)

What is evolution?

- **Evolution**—changes (adaptations) that occur over time in a population
  - These changes tend to ensure the survival of a species
  - Can gradually lead to the development of new species

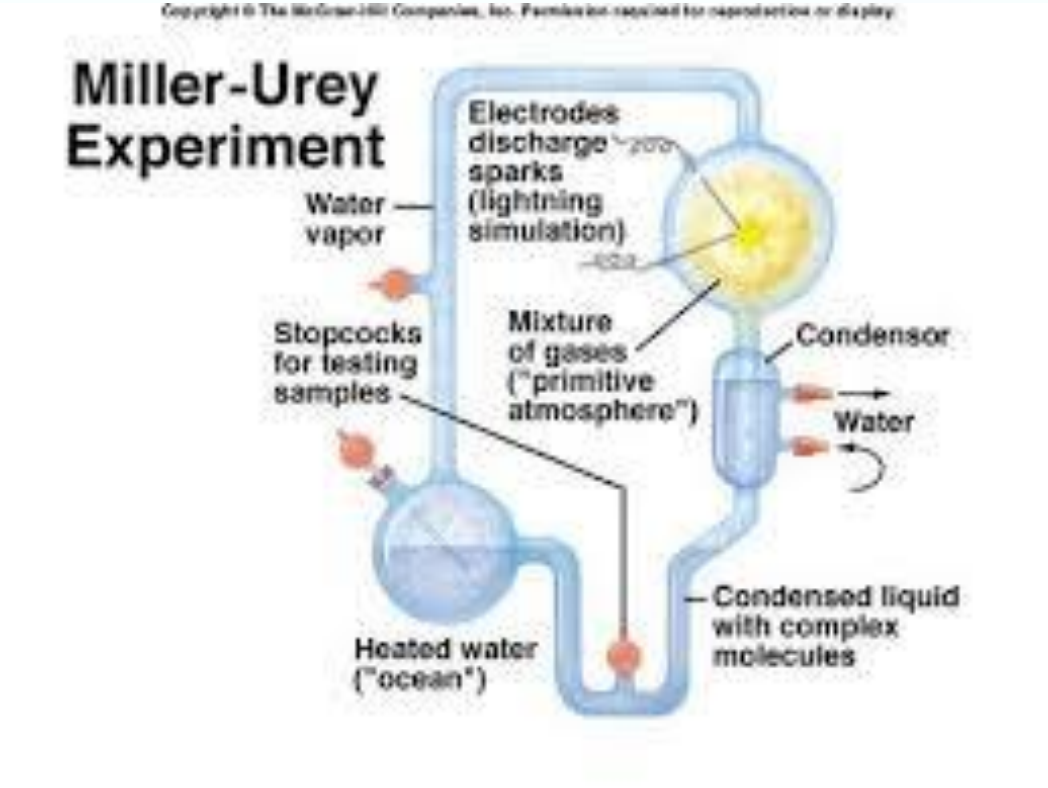
Populations evolve, not individuals!!!

History of Evolution

- **<u>Biogenesis</u>**—principle that states all living things come from other living things (what we know now)…recall the Cell Theory

- But before now…

what did people think?



History of Evolution

Early thought (circa 17th Century):

- **Spontaneous generation** — living things can arise from nonliving things
  - Ex: maggots arising from a piece of meat

History of Evolution-Fossils

- Biologists have used fossils in their work since the 1700's, but they still had a lot of unanswered questions from using them:
  - How were they formed?
  - Why are many fossil species extinct?
  - What kinds of relationships exist between the extinct species and modern ones?

History of Evolution

- Darwin started breeding pigeons to isolate and pass on desirable traits (like Mendel did with the pea plant). This is called artificial selection because HE was able to choose the traits being passed on.
- **Artificial selection**: process of breeding organisms with specific traits in order to produce offspring with those same traits.

Darwin

- Charles Darwin proposed the hypothesis that species were modified, or evolved, ***by nature itself*** in a process called natural selection and that OVER TIME, new species can be created

- **Natural Selection**—organisms better suited to an environment will live to reproduce. Those NOT suited will die ("bad" genes will be lost). This is commonly called "**survival of the fittest**."

Darwin

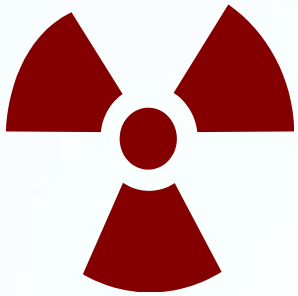
- **In 1859,** he published his findings in ***On the Origin of Species*** *by the Means of Natural Selection*. He provided a lot of evidence to support his hypothesis and scientists today also have many types of scientific methods that support his theory.

Evidence Supporting Evolution

1. Adaptations
2. Radioactive dating
3. Fossils
4. Comparative Anatomy
5. Biochemistry

Adaptations

1. These are direct evidence of evolution because they show firsthand the way populations of species have evolved in order to better adapt to their environment
   - Structural adaptations—claws, beaks, wings
   - Physiological adaptations—resistance to substances after constant exposure



Radioactive Dating

2. **Radioactive dating**—measuring the age of something by determining the amount of a radioactive *isotope* it contains (usually

Carbon-14)

- **must use an unstable isotope that decays (breaks down) over time like C-14
- **Isotope**—atoms of the same element that have different numbers of neutrons.

Carbon Dating

- **Half-life**—length of time it takes for ½ of any size sample of isotope to break down (1/10 second to 1 billion years)
- Example: Carbon-14 dating
  - Most carbon is C-12. C-14 is unstable radioactive isotope. All things with ANY carbon will have small amount of C-14. Since we know half-life of C-14, by measuring amount of C-14 left in something, we can ESTIMATE its age.

Fossils

3. **Fossils**—traces or remains of a dead organism from LONG ago
   - Can show structural similarities between extinct and modern species, implying a possible ancestor-descendant relationship

Comparative Anatomy

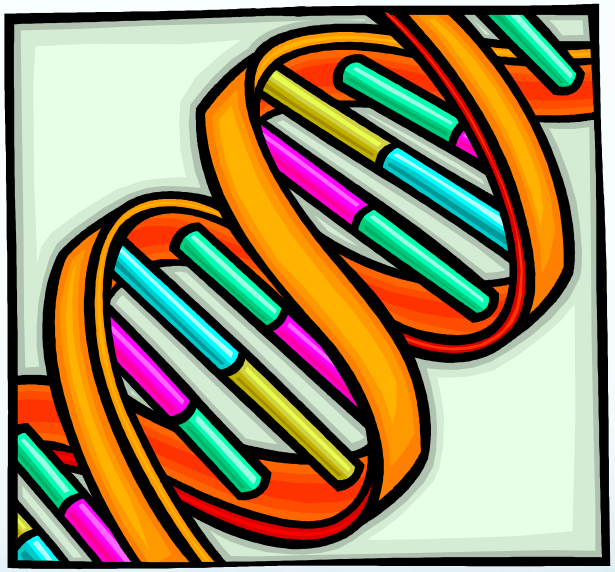
- Comparing the anatomical structures of species
- **Homologous structures**—similar features that originated in a shared ancestor and arise from same TYPE of structure
  - Ex: paws, hands, and bat wings (all mammalian)
- **Analogous structures**—structures that serve the same function and look alike, but do not come from common ancestor
  - Ex: wings on moth and wings on bird

Comparative Anatomy

- **Embryology**—study of embryos (developing babies)
  - Many developing embryos LOOK ALIKE, no matter the what the species is.
  - By comparing development, scientists can determine how closely related organisms are

Biochemistry

- Biochemistry is the study of the chemical interactions that occur in living organisms



- **DNA Sequencing**—by comparing the sequence of nucleotides, scientists can see how closely related organisms are at a molecular level.

Why Evolution Occurs

- Overall, evolution occurs because it allows populations to make adaptations to better survive in their environments
- Causes of Evolution:
  1. Mutations
  2. Migration
  3. Genetic drift
  4. Nonrandom mating
  5. Natural selection

1. Mutations

- A mutation is a random change in a gene or chromosome resulting in a new trait or characteristic that can be inherited.

- Mutations happen spontaneously

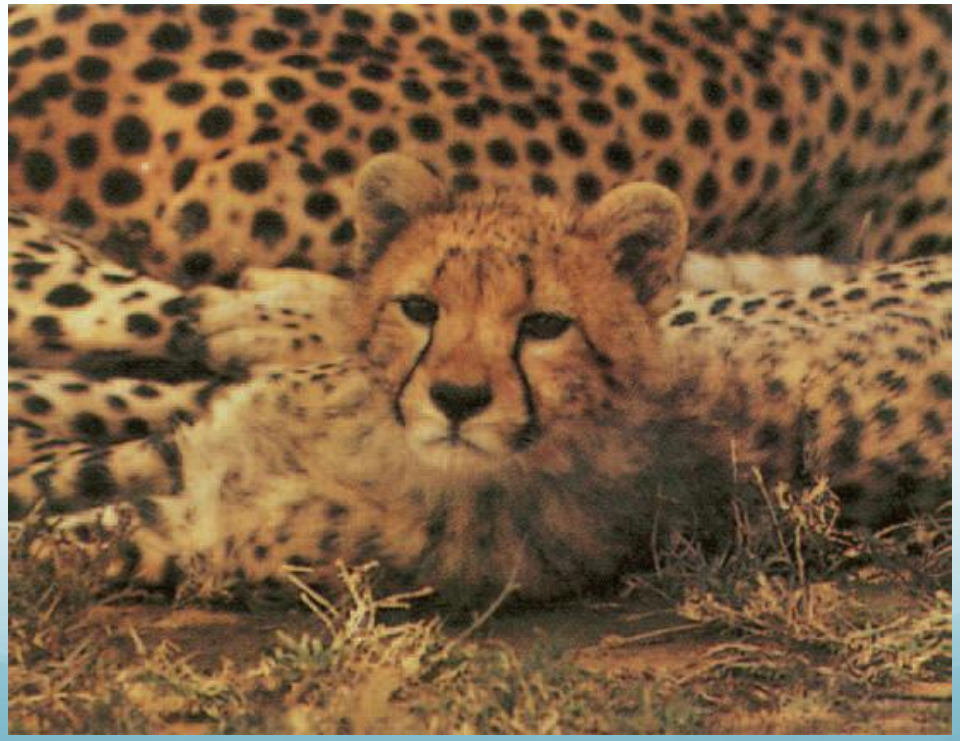
- Beneficial mutations can lead to adaptations (so not all are harmful)

2. Migration

- **Immigration:** movement of individuals INTO a population
- **Emigration:** movement of individuals OUT of a population
- Brings in new genes/alleles through gene flow
- **Gene flow**: process of genes moving from one population to another

3. Genetic Drift

- Happens when allele frequencies in a population change because of random events or chance
- Only matters w/ small or large populations



4. Nonrandom Mating

- Many species do not mate randomly
- Mate selection often affected by proximity → inbreeding
  - can amplify certain traits
- Selection also affected by: selecting a mate w/ similar physical characteristics.
  - Such mates probably carry similar genes

5. Natural Selection

- Is an ongoing process in nature because the environment changes and animals continue to naturally adapt as a means of survival
- ***Single most significant factor*** that causes evolution

Theory of Evolution

- Five related theories:
  - Perpetual change
  - Common descent
  - Multiplication of species
  - Gradualism
  - Natural selection

Theory of Evolution

- **Perpetual Change** – The world and the organisms living in it are always changing.
  - Supported by the fossil record.
  - The properties of organisms undergo transformation across generations throughout time.
  - Theory upon which the remaining 4 are based.

Theory of Evolution

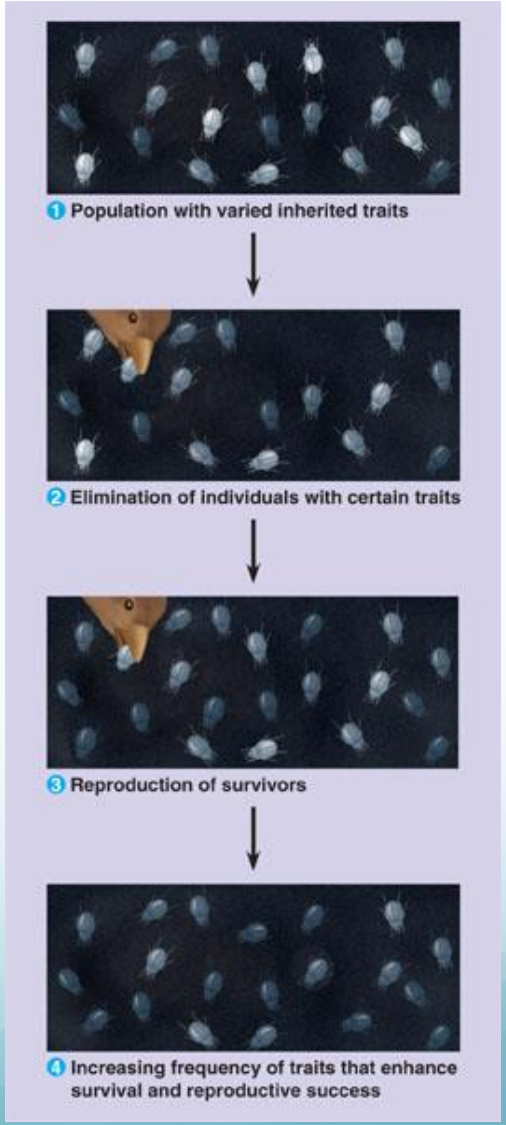
- **Common Descent** – All forms of life descended from a common ancestor through a branching of lineages.
  - Life's history has the structure of a branching evolutionary tree, known as a **phylogeny**
  - Serves as the basis for our taxonomic classification of animals
  - Descent with modification.
  - Supported by molecular work.

Theory of Evolution

- **Multiplication of Species** – New species are produced by the splitting and transforming of older species.
- **Gradualism** – Large differences result from the accumulation of small changes over long periods of time.
  - Occasionally, changes can happen more quickly.

Theory of Evolution

- **Natural Selection** – Differential success in the reproduction of different phenotypes resulting from the interaction of organisms with their environment.



Theory of Evolution

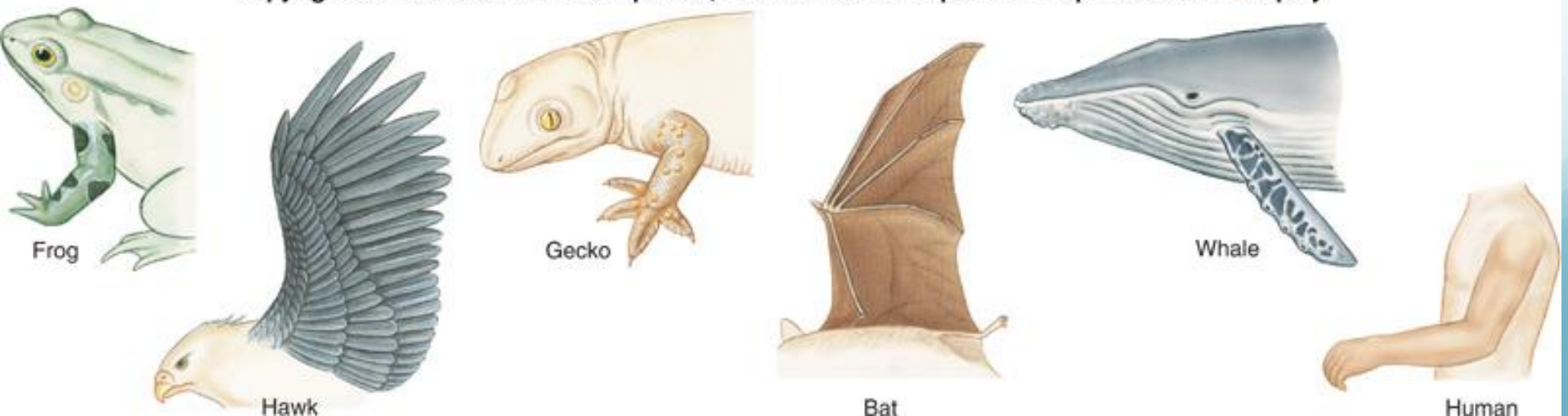
- Natural selection requires:
  - **Variation** within the population.
  - This variation must be **heritable**.
  - Organisms with a particular variation will have more offspring.
- Over time, these successful variations will spread through the population.

Adaptation

- Natural selection explains why organisms are constructed to meet the demands of their environments.
- **Adaptation** results when the most favorable variants accumulate over evolutionary time.

Unity in Diversity

- All vertebrate forelimbs share an underlying structure utilizing the same parts, but have evolved a diverse array of adaptations, as seen in the wing of a bat, the flipper of a whale, & a human arm.



Mendelian Heredity

- Darwin knew that some traits were heritable, but he didn't have an understanding of the ***mechanism*** of heredity.

Mendelian Heredity

- **Gregor Mendel** performed experiments on garden peas leading to an understanding of how chromosomal inheritance works.

Mendel's Peas

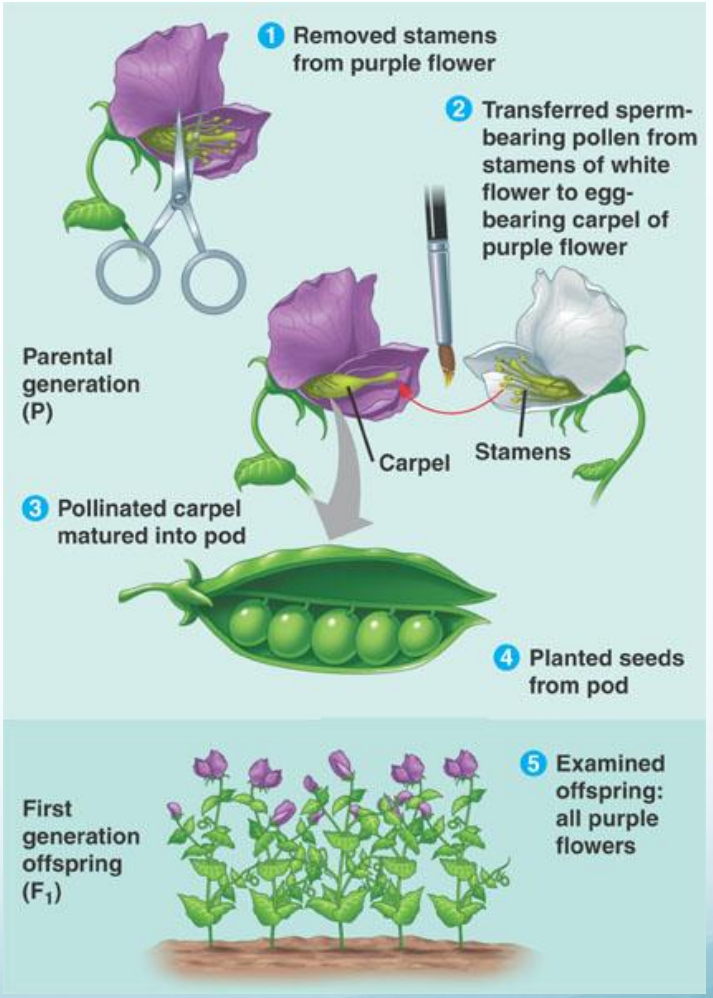
- Mendel chose peas to study inheritance because they possess several contrasting **traits** without intermediates.
  - Green vs. yellow peas
  - Tall vs. short plants
  - Wrinkled vs. smooth peas
  - Purple vs. white flowers

Mendel's Peas

- The peas can self-fertilize or outcross.
  - Mendel could control who the parents were.
- Mendel always started with **true-breeding** parents.
  - E.g. self-fertilized white flowered parents *always* produced white flowered offspring.

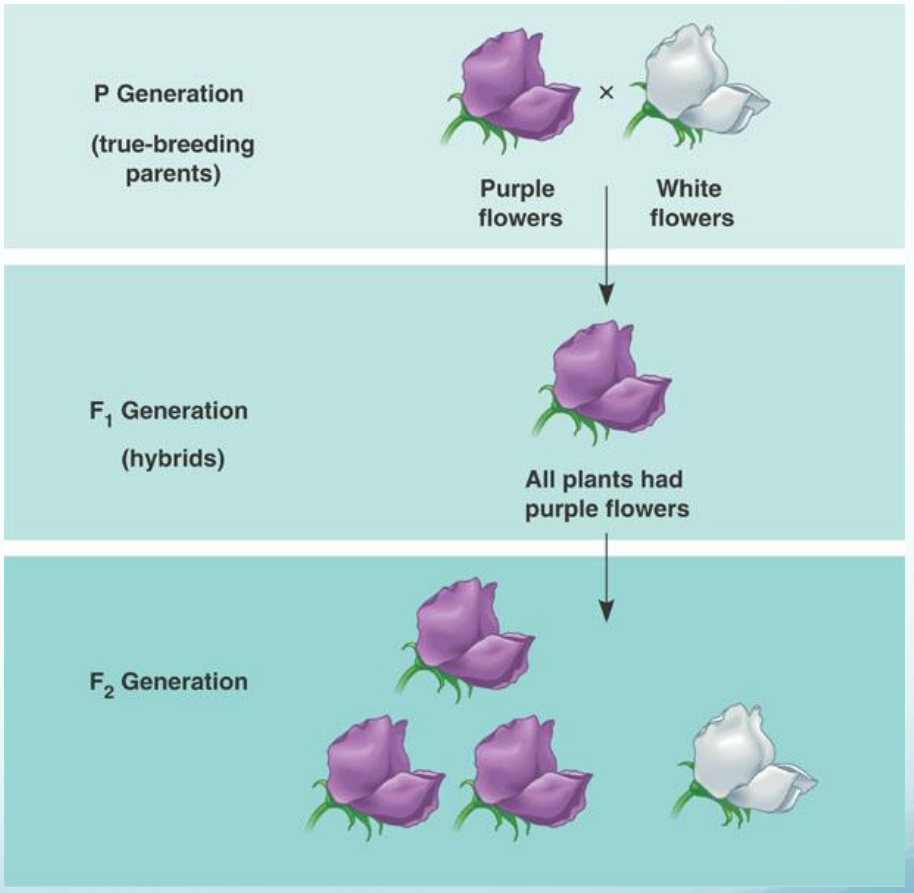
Mendel's Peas

- He could cross true breeding white with true breeding purple – this is the parental generation.
- Resulting in all purple offspring – this is the F_1 generation.



Mendel's Peas

- Allowing the hybrid F_1 generation to self pollinate gives the F_2 generation with 3 purple: 1 white offspring.
- He kept careful ***quantitative*** records that allowed him to find patterns.



Contributions of Cell Biology

- Microscopes allowed scientists to study the production of gametes (eggs & sperm).
- They could watch the movement of chromosomes.
- Result: the **chromosomal theory of inheritance**.
  - Heritable information is contained on chromosomes.