**Chapter 1**

The Science of Life

* **Biology** unifies much of natural science
* Life ***defies*** simple definition
	+ Living systems are the most complex chemical systems on Earth
	+ Life is constrained by the properties of chemistry and physics
* Science is becoming more ***interdisciplinary***
	+ Combining multiple fields

**7 characteristics of all living organisms**

* 1. Cellular organization
	2. Ordered complexity
	3. Sensitivity
	4. Growth, development, and reproduction
	5. Energy utilization
	6. Homeostasis
	7. Evolutionary adaptation

Living systems show **hierarchical organization**

* Cellular level
* Organism level
* Population level
* Ecosystem level
* Biosphere

Living systems show **hierarchical organization**

* **Cellular level**
	+ Atoms, molecules, organelles, cells
	+ Cell is the basic unit of life
* **Organism level**
	+ Tissues, organs, organ systems
* **Population level**
	+ Population, community
* **Ecosystem level**
* **Biosphere**
	+ All the livable space on the planet
	+ 99% of it is in the ocean!!!

As you move up the hierarchy, novel properties emerge

* Result from interaction of components
* Cannot be deduced by looking at parts themselves

***Science*** aims to understand the natural world through observation and reasoning

Science begins with **observations**, therefore, much of science is purely descriptive

* Classification of all life on Earth
* Human genome sequencing

Science uses both ***deductive*** and ***inductive*** reasoning

* **Deductive reasoning** uses general principles to make specific predictions
	+ - If all mammals have hair and you find an animal that doesn’t, you might say that the animal you are looking at is not a mammal
		- Used to test the validity of general ideas in all branches of knowledge
* **Inductive reasoning** uses specific observations to develop general conclusions
	+ - If poodles have hair and terriers have hair, then you might generalize that all dogs have hair
* Scientists use a systematic approach to gain understanding of the natural world

***Scientific Method***

* + Observation
	+ Hypothesis formation
	+ Prediction
	+ Experimentation
	+ Conclusion
* A **hypothesis** is a possible explanation for an observation
	+ - Not just an “educated guess”
* A hypothesis
	+ Must be tested to determine its validity
	+ Is often tested in many different ways
	+ Allows for predictions to be made
* Interactive
	+ Hypotheses can be changed and refined with new data
* **Experiment**
	+ Tests the hypothesis
	+ Must be carefully designed to test only one variable at a time
	+ Consists of a **test experiment** and a **control experiment**
* **Predictions**
	+ Hypotheses should make predictions
	+ Predictions provide a way to test the validity of hypotheses
	+ Hypothesis must be rejected if the experiment produces results inconsistent with the predictions
	+ The more experimentally supported predictions a hypothesis makes, the more valid the hypothesis

Philosophical approaches to science

* **Reductionism**
	+ To break a complex process down to its simpler parts
	+ For example
		- Cellular metabolism is very complex, reductionism is looking at one pathway and the function of that enzyme
		- However, that enzyme may work differently when not isolated from other enzymes and molecules within the cell
* **Systems biology**
	+ Focus on emergent properties that can’t be understood by looking at simpler parts
* **Models** in science
	+ Way to organize thought
	+ Parts provided by reductionist approach
	+ Model shows how they fit together
	+ Suggest experiments to test the model
* **Scientific theory**
	+ Is a body of interconnected concepts
	+ Is supported by much experimental evidence and scientific reasoning
	+ Expresses ideas of which we are most certain
	+ When you say “theory” in science, it is as close to fact that you will get to with the information and technology we have available to us at the time
	+ Compare to general meaning of theory
	+ Different in everyday language, implies a lack of knowledge or a guess

**Darwin and Evolution**

* Example of how a scientist develops a ***hypothesis*** and a ***theory*** gains acceptance
* **Charles Darwin** served as naturalist on mapping expedition around coastal South America
* 30 years of observation and study before publishing *On the Origin of Species by Means of Natural Selection*
* Darwin was not the first to propose ***evolution***
	+ Living things have changed over time
* Darwin’s contribution was a mechanism for evolution
	+ **He proposed Natural selection**
* On the *Beagle*, Darwin saw that characteristics of similar species varied from place to place
* Galápagos Finches
	+ 14 related species differ only slightly
	+ “Descent with modification” or evolution
* Darwin studied Thomas Malthus’s *An Essay on the Principle of Population*
	+ Populations of plants and animals increase **geometrically** (multiplicative, example x3)
	+ Humans can only increase their food supply **arithmetically** (additive, example +2)
	+ Populations of species remain constant because death limits population numbers
	+ There are individuals that possess physical, behavioral or other attributes that give them an advantage

Darwin saw that:

* Every organism has the potential to produce more offspring
* But, only a limited number survive and reproduce themselves

Darwin made an important association:

* Individuals with attributes that give them an advantage in their environment are more likely to survive and reproduce
* Pass these characteristics on to their offspring
* The population will gradually change over time
* Darwin called this ***selection***
* Evidence supporting Darwin’s theory has only grown
	+ **Fossil record**
	+ **Earth’s age**
	+ **Mechanism for heredity**
	+ **Comparative anatomy**
	+ **Molecular Evidence**
	+ **Fossil record**
		- Transitional forms have been found at predicted positions in time
	+ **Earth’s age**
		- Earth is very old – 4.5 billion years old
	+ **Mechanism for heredity**
		- Mendel’s laws of inheritance were unknown to Darwin
		- At time of Darwin there was no concept of “genes” or how heredity worked
		- Darwin could not completely explain how evolution worked
		- Now have detailed understanding of **heredity**
	+ **Comparative anatomy**
		- Vertebrate forelimbs all share the same basic array of bones
		- **Homologous** – same evolutionary origin but now differ in structure and function
		- **Analogous** – structures of different origin used for the same purpose (butterfly and bird wings)

**Cell theory**

* + All organisms composed of cells
	+ Cells are life’s basic units
	+ All cells come from preexisting cells
* **Molecular basis of inheritance**
	+ Deoxyribonucleic acid (DNA)
	+ Sequence of 4 nucleotides encode all of a cell’s information – A, T, C, G
	+ Gene – discrete unit of information
	+ Genome – entire set of DNA instructions
	+ Continuity of life depends on faithful copying of DNA into daughter cells
* **Structure and function**
	+ Study structure to learn function
	+ Know a function – look for that structure in other organisms
	+ Example
		- Receptor on human cell for insulin known
		- Find similar molecule in a worm
		- Might conclude this molecule functions the same in the worm
* **Diversity of life arises by evolution**
	+ Underlying unity of biochemistry and genetics argues for life from the same origin event
	+ Diversity due to evolutionary change over time
	+ 3 domains
		- Bacteria – single-celled prokaryote, bacteria
		- Archaea – single-celled prokaryote, includes extremophile bacteria
		- Eukarya – single-celled or multicellular eukaryote; includes protists, fungi, plants, and animals.
* **Evolutionary conservation**
	+ All organisms today descended from a simple creature 3.5 BYA
	+ Some characteristics preserved
		- * Our DNA encodes everything
			* For example, you need certain enzymes for cellular respiration, those are encoded in your DNA; those same enzymes are used by other organisms for the same process
	+ Conservation reflects that they have a fundamental role
* **Cells are information-processing systems**
	+ Information in DNA used to direct synthesis of cellular components
		- Control of gene expression leads to different cells/ tissue types
	+ Cells process environmental information
		- Glucose levels, presence of hormones
	+ Cells in multicellular organisms must coordinate with each other
* **Nonequilibrium state**
	+ Living systems are open systems
	+ Constant supply of energy needed
	+ Self-organizing properties at different levels
	+ Emergent properties from collections of molecules, cells, and individuals