Introduction: Themes in the Study of Life
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Slide 1
Though it is difficult to provide a rigorous definition of "living thing", all living things share some important characteristics:

- A living thing responds to the environment in which it lives.
- A living thing is capable of reproduction, whether alone (asexually) or with the cooperation of a mate (sexually).
- Though unicellular organisms undergo little growth, a multicellular organism undergoes extensive growth (by adding more cells) and development (by changing form and function during some part of the lifetime).
- A living thing must process energy to supply the needs of life. Life is a large set of chemical reactions occurring in the cell or cells of an organism.
- The large set of chemical reactions occurring within an organism must be regulated; otherwise the organism will die. Regulation is achieved through feedback, which allows for homeostasis.
- A living thing possesses a high degree of order compared to most non-living things.
- Over the course of many generations, species become more and more adapted to their environments. This adaptation is driven by evolution, whereby an accidental mutation that happens to be beneficial to the organism will provide that mutant organism a greater chance of surviving long enough to reproduce. By reproducing, the mutant organism passes on the new and beneficial trait to the next generation, whereas harmful mutations (resulting in reduced chance of reproduction) will less likely be passed on.

Slide 2
Biology can be studied at many different levels, reflecting a hierarchical arrangement of biotic and abiotic entities.

- At the small end of the hierarchy are atoms, of which all material things are made.
- Atoms combine to form larger structures called molecules.
- Molecules combine to form structures called organelles. These function as "tiny organs" within cells.
- Organelles of different types make up a cell, which is the fundamental unit of organisms.
- In multicellular organisms, collections of cells form tissues.
- In multicellular organisms, different tissues make up an organ.
- In multicellular organisms, a collection of functionally related organs make up an organ system.
- In multicellular organisms, all of the different organ systems constitute the organism. For a unicellular organism, the Cell level and the Organism level are the same thing, and the levels in between the two are not applicable.
- Multiple individuals of the same species living in a specific space make up a population.
- Multiple populations (different species) living in the same space make up a community. A community includes only the living things in that space.
- An ecosystem includes a community (the biotic entities) as well as the non-living (abiotic) entities in that space.
- The biosphere is the collection of all known ecosystems.

Slides 3 & 4
Energy (which is not material) flows through an ecosystem, whereas materials (things made of atoms) cycle within an ecosystem. Energy enters as sunlight. That energy gets transformed and transferred in the ecosystem, and the energy eventually leaves the ecosystem as heat. Meanwhile, the materials that make up that ecosystem get transferred between biotic and abiotic constituents of that ecosystem, but the materials remain largely within the ecosystem.

Slide 5
Because of evolutionary adaptation, there is a close relationship between form and function. Random mutations change the structural form into which an organism develops. Those mutations that happen to "work" well are favored. Therefore, because of evolution, an organism has its specific structure (form), because that structure allows it to function well in its environment. An organism's current form reflects an evolutionary accumulation of many tiny, stepwise changes that occurred over many generations.

Slide 6
An organism is something that consists of at least one cell. Cells can be classified into two types:

- A prokaryotic cell does not contain a true nucleus, and it does not contain any other membrane-bounded organelles.
- A eukaryotic cell contains a true (membrane-bounded) nucleus as well as other membrane-bounded organelles.

Any cell possesses a plasma membrane that separates the intracellular fluid from the extracellular fluid. With its single membrane, a prokaryotic cell contains only one compartment. The materials within that compartment are collectively called the cytoplasm. A eukaryotic cell contains two major compartments (one outside the nucleus and one inside the nucleus). The cytoplasm includes all the cell contents that are outside the nucleus. The contents of the nucleus are called the nucleoplasm.

Slide 7
The Cell Theory states that all cells now come from preexisting cells. In other words, cells are no longer forming out of abiotic raw materials like they did at the beginning of life on this planet. Rather, new cells are created when a cell splits into two new cells, or when two cells fuse. For example, both of these processes come into play in the creation of a multicellular animal like a human, as the slide demonstrates. Fertilization combines two cells (sperm and egg) to produce a new cell (a zygote), which then undergoes multiple rounds of cell division to produce a multicellular baby.

Slide 8
Evolution operates, because organisms pass on traits to their offspring. The passing of traits to offspring occurs because DNA is transferred from parent cell to offspring cell, and because DNA indirectly determines traits. DNA (deoxyribonucleic acid) is a type of biological macromolecule that serves as a set of codes for how to indirectly construct proteins within a cell. Those proteins directly give the organism its traits. In a eukaryotic cell, DNA is found in the nucleus. DNA in a prokaryotic cell is found in a region of the cytoplasm called the nucleoid.

Slide 9
Feedback exists when something in a process gets fed back into an earlier part of the process. As part of regulation, organisms keep track of several variables (e.g., temperature, pH, etc.). For each regulated variable, there is a set point, which is the desired value of that variable. The actual value of that variable might differ from the setpoint (in either direction, too high or too low). If so, that difference is called the error. Two kinds of feedback occur in organisms:

- In negative feedback, the error is reduced, because some change is made to bring the variable closer to the set point. In so doing, negative feedback leads to homeostasis, which is maintenance of a relatively stable internal environment in an organism. Negative feedback is the only kind of feedback that can lead to homeostasis, and it is much more common than positive feedback.
- In positive feedback, the error is made even worse, because some change is made that moves the value of the variable even farther from the set point. Positive feedback mechanisms are much more rare in organisms, and all positive feedback mechanisms are temporary.

Slide 10
Taxonomy is a hierarchical system of classifying organism into different groups of increasing size based on shared traits. Groups range from species at the small end of the hierarchy to domains at the large end.

Slide 11
Current taxonomy recognizes three domains of life:

- Bacteria - All members of Bacteria are unicellular and prokaryotic.
- Archaea - All members of Archaea are unicellular and prokaryotic, but they differ from members of Bacteria is several structural and biochemical ways.
- Eukarya - This domain includes all of the organisms consisting of eukaryotic cells. Some are unicellular; most are multicellular.

While all eukaryotes are in Eukarya, the prokaryotes are separated into the other two domains.

Slide 13
A population includes individuals with a variety of traits. When a change occurs in the environment, a population evolves, because a trait that was previously beneficial might now be detrimental, and vice versa. Therefore, those individuals having the beneficial trait will enjoy a greater likelihood of reproducing, thus passing that beneficial trait to the next generation. In this way, the next generation will include a higher fraction of individuals with the beneficial trait and a lower fraction of individuals with the detrimental trait.

Slide 15
There is a fundamental difference between religion and science. Religion involves belief based on faith in the absence of evidence, whereas science involves belief based on evidence only. The scientific method is a way to test explanations about the universe, so that we can objectively determine what is true about our surroundings. Humans observe various things about their surroundings and question why things are that way. A scientist comes up with a hypothesis, which is an explanation for the observation. A hypothesis might be a completely incorrect explanation, so a scientific hypothesis must be tested by experimentation. Each hypothesis implies a specific prediction that would come true if the hypothesis were correct. Therefore, a scientific experiment is a way to see whether a hypothesis' prediction comes true. If a prediction does not come true, that is an indication that the corresponding hypothesis is not correct, and an alternative hypothesis must be made. If a prediction comes true, that is an indication that the corresponding hypothesis might be true, but it does not prove that it is true. Science can never prove things to be true. However, things that we call facts (like gravity or evolution) are things that never fail in repeated experimentation. Sometimes, what we had been calling a fact is found to fail experimentation, and scientists are forced to revise the set of facts. This would happen for gravity, for instance, if suddenly someone were to obtain the experimental result that a dropped object rises instead of falls.