BIOLOGY

Biology: **the study of life**
Organisms: **all living things**
There have been different views of life throughout history.

1. **<u>vitalism:</u> living things exist because they have been filled with special forces, called ethers, which bring nonliving things to life**
   Vitalism was the main view of life for about 2000 years until the Dark Ages, when the idea of spontaneous generation came around.

2. **<u>spontaneous generation:</u> a theory stating that living organisms are produced from nonliving matter and ethers**
   examples: maggots from rotting meat
   mice from old rags
   geese from river banks

1668 – Francesco Redi tests spontaneous generation. Redi thought that maggots came from flies, not from ethers. So he put some rotting meat in jars.

1. **When the jars were left open → maggots appeared (Both flies and ethers could get into the jar. What does this show?)**
2. **When the jars were sealed → no maggots (Neither the ethers nor the flies could get into the jar. What does this show?)**

3. When the jars were covered with cloth → no maggots
(Ethers could get in but flies could not. What does this show?)

Redi's experiment supported another theory that eventually replaced spontaneous generation → biogenesis.

3. <u>biogenesis:</u> principle that life comes only from life
"bio" = life "gen" = to make, produce
→ Each type of living organism produces more of its own kind.

But it wasn't as if everyone let go of spontaneous generation and immediately embraced biogenesis. In fact, Redi's work and conclusions were questioned and tested for the next 200 years.

Background info: Microorganisms (bacteria, protists, etc.) were first observed around the same time as Redi was completing his maggot experiments.

John Needham – mid 1700's – English scientist

- **claimed that spontaneous generation could occur under the right conditions**
- **Needham sealed a bottle of gravy and heated it. He claimed that the heat would kill any living things in the gravy. After several days, the gravy was teeming with microorganisms.**
- **Needham's (incorrect) conclusion: The micro-organisms only could have come from the gravy itself.**

Rebuttal of Needham's Work:
Lazzaro Spallanzani – Italian scientist

- **He thought that Needham had not heated his samples of gravy to a temperature high enough.**
- **Spallanzani <u>boiled</u> 2 flasks of gravy. He assumed that boiling would be enough to kill any micro-organisms already in the gravy.**
- **Immediately after boiling, he sealed one of the flasks of gravy. The other was left open.**
- **After a few days, the open jar was full of micro-organisms. The sealed jar had none.**
- **Spallanzani's Conclusion: Gravy did not produce microorganisms. The microorganisms in the open jar had come from microorganisms in the air that had multiplied in the gravy.**

Despite Spallanzani's work, some scientists still continued to support spontaneous generation well into the 1800's. They argued that <u>air</u> contained a "life force" necessary for generating life, and therefore Spallanzani's work was not conclusive.

Louis Pasteur – 1864 – French scientist

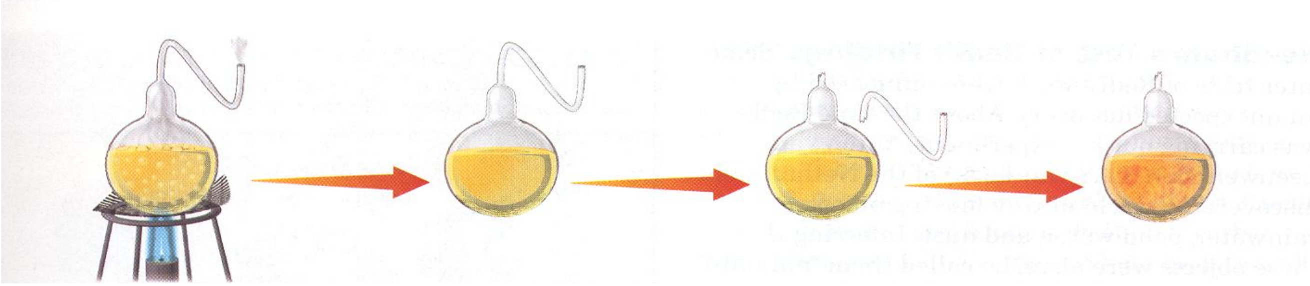
- **Designed a flask to settle the argument.**
- **The flask had a long curved neck. Air could get in, but microorganisms from the air could not make their way through the neck into the flask.**
- **Broth was boiled in this flask and without being sealed, it remained free of microorganisms for an entire year. As long as it was protected from**

microorganisms, the broth remained free of living organisms.

- After one year, Pasteur broke off the curved neck of the flask, and the broth quickly filled with micro-organisms.

Pasteur's experiment finally convinced other scientists that spontaneous generation was incorrect. It also provided very strong support for biogenesis.

Louis Pasteur's Test of Spontaneous Generation



Broth is boiled.	Broth is free of microorganisms for one full year.	Curved neck is is removed.	Broth is teeming with microorganisms.

Side Note: We've been talking about hypotheses and theories. The word "theory" has a different meaning in science than in other areas. In science, a theory is a well tested explanation that unifies a broad range of observations. Theories are extremely well supported by vast amounts of experimentation, data collection, and scrutiny. It is not an "educated guess" like a hypothesis.

As more information is gained with advances in technology and further research, a theory is constantly analyzed, reviewed, and if necessary, revised.

Properties of Life

I. Living things are made up of units called cells.
II. Living things reproduce.
III. Living things are based on a universal genetic code.
IV. Living things grow and develop.
V. Living things obtain and use materials and energy.
VI. Living things respond to their environment.
VII. Living things maintain a stable internal environment.
VIII. Taken as a group, living things change over time.

We're going to take a brief look at each one of these properties and later in the course, take a much deeper look at some of them. Remember, every textbook you pick up could have a different list. There is no set list of properties that is universally accepted.

I. Living things are made up of cells.

Cell – collection of living matter enclosed by a barrier that separates the cell from its surroundings; basic unit of all forms of life

- **A. Cells can grow, respond to the environment, and reproduce; they are complex and highly organized.**
- **B. Organisms can be made of one cell or many cells.**
    1. **unicellular – "single celled" – organisms consisting of only one cell**

2. **<u>multicellular</u> – "many celled" – organisms consisting of hundreds, even trillions of cells**
   a. **often has a diversity of cells with different functions**
   b. **sizes and shapes of cells differ also within the organism**

II. Reproduction

A. **All organisms produce new organisms through reproduction.**

B. **Two basic kinds of reproduction:**

1. **<u>sexual reproduction</u>:**
   a. **cells from 2 different parents unite to produce the first cell of the new organism**
   b. **the majority of multicellular organisms use sexual reproduction**
2. **<u>asexual reproduction</u>:**
   a. **a single parent reproduces by itself**
   b. **there are many different ways that asexual reproduction can happen**
      - **a single celled organism divides in half to form 2 new organisms**
      - **a portion of an organism splits off to form a new organism**

III. Based on a Genetic Code

A. **Traits are inherited from parent to offspring. In asexual reproduction, parents and offspring have the same traits. In sexual reproduction, offspring are different from their parents, within limits.**

B. DNA, or deoxyribonucleic acid, is the molecule that holds the directions for these patterns of inheritance.
C. Every single living organism has DNA, the genetic code.

IV. Growth and Development

A. All living things grow during at least part of their lives.
<u>growth</u> – increase in size

B. Multicellular organisms also go through a process called development.
1. **As cells divide in early stages of life, they change in shape and structure to form cells such as liver cells, brain cells, lung cells, etc.**
2. **This process is called <u>differentiation</u> (also called <u>cell specialization</u>) – process in which cells become specialized in structure and function**

V. Need for Materials and Energy

A. To grow, develop, reproduce, and just to stay alive, living things need energy and materials.
1. **<u>metabolism</u>: set of chemical reactions through which an organism builds up or breaks down materials as it carries out life processes**
2. **Organisms have many different ways of obtaining energy from their environments.**
    a. **plants, some bacteria, most algae – photosynthesis**

b. other organisms eat those organisms that use photosynthesis

c. There are other chemical ways besides photosynthesis to get energy from the environment, but they are not very common.
e.g. chemoautotrophs

VI. Response to the Environment

A. Organisms detect and respond to stimuli in the environment.

1. **<u>stimulus</u> (plural stimuli) – a signal to which an organism responds**
2. **<u>internal stimulus</u> – comes from within the organism**
   e.g. hungry feeling when sugar levels are low
3. **<u>external stimulus</u> – environment outside the organism gives a signal**
   e.g. sunlight amounts, temperatures, gravity

VII. Maintaining an Internal Balance

A. Though conditions in the environment can vary widely, internal conditions for organisms must be kept fairly constant e.g. temperature, hydration.

1. **<u>homeostasis</u> – process by which organisms maintain a relatively stable internal environment**
2. **often involves internal feedback systems**
   e.g. too hot – body sweats to cool itself
   too cold – body shivers to produce heat

VIII. Evolution

A. Although individual organisms go through changes, the basic traits they inherited from their parents do not - eye color, skin color, etc.

1. **However, as a GROUP, any given kind of organism can evolve, or change over time.**
2. **It takes a very long time for change to appear, hundreds, thousands, even millions of years.**

B. The ability for a group of organisms to change over time is invaluable for survival in a world that is always changing.

How might global warming affect evolution?

<u>Branches of Biology and the Organization of Life</u>

Life has many different levels of organization. All of them are open to study and have different specialties associated with them. The following section is a hierarchy, or arrangement, of these levels of life.

1. **<u>atoms & molecules:</u> Atoms are the smallest parts of ALL MATTER, living or nonliving. Molecules are groups of atoms and have different properties than the atoms by themselves.**

2. **<u>cell:</u> made up of groups of atoms and molecules; smallest unit of life**

3. **<u>tissue:</u> group of similar cells that perform a specific function; examples – muscle, bone, blood**

4. **<u>organ:</u> group of tissues that work together to perform closely related functions ex. – heart, leaves, kidneys**

5. **<u>organ system:</u> group of organs working together to perform a specific function; ex. digestive, circulatory**

6. **<u>organism:</u> an individual living thing**

7. **<u>population:</u> group of organisms of one type that live in a particular area**

   ex. snapping turtles in Farmer Smith's pond
   Yellow bellied sapsuckers living in Raccoon Creek State Park

8. **<u>communities:</u> all of the populations that live together in a defined area**

   ex. the lawn in your front yard – worms, ants, beetles, grass, fungi (BUT NOT the water, soil, minerals, sunlight, and rain)

9. **<u>ecosystem:</u> the community and its nonliving surroundings**

10. **<u>biosphere</u> – the parts of the Earth that contain all ecosystems**

Parts of the Atom

Nucleus: center of the atom, contains protons and neutrons

Energy level: outside of the nucleus where you are likely to find electrons

Protons: have a positive charge (+)

Electrons: have a negative charge (e^-)

Neutrons: have no charge (neutral)

The number of protons determines to what element the atom belongs (e.g. 8 protons means it's an atom of oxygen, 10 protons means it's an atom of neon).

The atomic number is equal to the number of protons in 1 atom of that element.

Atoms are neutral; they must contain equal numbers of protons and electrons.

To find the number of neutrons in an atom, round the atomic weight to the nearest whole number. Then subtract the atomic number from the atomic weight.

Diagram of a Lithium (Li) Atom:

The first energy level is full with 2 electrons. The second energy level is full with 8 electrons. The 3rd energy level can hold a maximum of 18 electrons.

Atoms like to exist with complete outermost energy levels. To achieve this, atoms lose or gain electrons, becoming ions.

Ion – an atom with an electrical charge due to a loss or gain of electrons

Example: Lithium has to either gain 7 electrons or lose 1 electron to get a full outermost energy level. Which is easier? Losing 1 electron!

Diagram of a Lithium Ion (Li^{+})

Take a look at oxygen and do the same thing.

Oxygen Atom: **Oxygen Ion (O^{-2})**

Oxygen can either lose 6 electrons or gain 2 electrons. It's much easier to gain 2 electrons. When this happens, oxygen picks up a -2 charge as an ion.

Try to determine what Magnesium does – its symbol is Mg.
The atomic number is 12, so that means 12 protons and 12 electrons in the Mg atom. The atomic weight rounds to 24. After you subtract the number of protons from 24, you end up with 12 neutrons.

Mg Atom:

Magnesium's 12 electrons require use of the 3rd energy level. There are only 2 electrons in this level and it's much easier to lose those 2 electrons than to gain 16 more electrons. So the Mg ion looks like this:

Mg Ion:

The symbol for this ion is : Mg^{+2}

I. Properties of Water

There is something special about water. Its very presence can indicate life on another planet. The role that water plays in living things is unique and vital.

A. Polarity :

Water is neutral (10 electrons balance out 10 protons). Remember that water is formed from covalent bonds between an oxygen atom and two hydrogen atoms. However:

1. **There is a greater probability of finding the shared electrons in water closer to the oxygen atom than near the hydrogen atoms. (covalent bonding forms water, so electrons are shared between oxygen and hydrogen)**
2. **As a result, the oxygen end of the molecule has a slight negative charge and the hydrogen end has a slight positive charge.**
3. **Polar: describes a molecule in which the charges are unevenly distributed**
4. **Note: polar charges are written in parenthesis (+), (-) to show they are weaker than the ionic charges of ions.**

B. Hydrogen Bonding

Because polar molecules have partial positive and negative charges, polar molecules can attract each other.

1. **Hydrogen bond: pretty strong attraction between a hydrogen atom and other atoms that have certain characteristics (very high electronegativity)**
2. **Not nearly as strong as covalent or ionic bonds**

C. Because it's polar, water is able to form multiple hydrogen bonds, giving it many special properties.

1. **Cohesion: attraction between molecules of the same substance**
   a. **Since water molecules can form up to 4 hydrogen bonds at the same time, water is extremely cohesive, causing water molecules to be drawn together.**
   b. **This is why water forms beads on a smooth surface. Cohesion also produces surface tension, which is how those very lightweight insects can walk on the water's surface.**
2. **Adhesion: attraction between molecules of different substances**
   a. **Water often adheres to other surfaces**

b. As a result of adhesion between water and glass, a meniscus forms in a graduated cylinder. The water on the sides rises, and the water in the center dips slightly downward.

c. Water will also rise in a narrow tube, against the force of gravity. This is called capillary action and is a result of adhesion. Capillary action helps to draw water out of a plant's roots and up through its leaves.

3. Heat Capacity: the amount of heat energy needed to increase the temperature of a substance

a. The heat capacity of water is especially high because of the numerous hydrogen bonds it can form.

b. Large bodies of water can absorb large amounts of heat without large changes in temperature.

II. Acids, Bases, and pH

A. Water molecules sometimes split apart to form ions, H^+ and OH^-. It doesn't happen very often and the reaction can happen in the opposite direction as well.

$$\underset{\text{water}}{H_2O} \longleftrightarrow \underset{\text{hydrogen ion}}{H^+} + \underset{\text{hydroxide ion}}{OH^-}$$

1. **Since there are equal numbers of positive hydrogen ions and negative hydroxide ions, PURE water is neutral.**

B. pH scale: measures the concentration of H^+ ions in a solution

1. **Ranges from 0 to 14.**
2. **Solutions with a pH below 7 are acidic (acids) because they have more H^+ ions than OH^- ions. The lower the pH, the stronger the acid.**
3. **Solutions with a pH above 7 are basic (bases) because they have more OH^- ions than H^+ ions.**
4. **Pure water has equal amounts of ions, so its pH is 7, neutral, making it neither acidic nor basic.**

C. Acids

1. **Acid: any compound that forms H^+ ions in solution**
2. **Strong acids usually have a pH from 1 to 3**
3. **Acid in your stomach (hydrochloric, HCl) is about 1.5 on the pH scale**

D. Bases

1. **Base: any compound that produces OH^- ions in solution**
2. **Also called *alkaline***
3. **Many cleaning products, such as soap, ammonia solutions, and bleach, are basic**

III. The Chemistry of Carbon

A. Organic vs. Inorganic

1. **organic compounds: contain carbon (C)**
   a. **Carbon dioxide: CO_2**
   b. **Methane: CH_4**
2. **Inorganic compounds: do not contain carbon**
   a. **Sodium chloride: NaCl**
   b. **Water: H_2O**

B. Carbon has some very interesting characteristics which give it some amazing abilities.

1. **Carbon has 4 valence (or outer) electrons.**
   a. **Allows carbon to form strong covalent bonds with many other elements**
   b. **Some other elements it commonly bonds with include hydrogen, oxygen, phosphorus, sulfur, and nitrogen**
   c. **Most of the compounds making up living organisms contain carbon and these elements**
2. **One carbon atom can bond with another carbon atom**
   a. **Carbon is able to form chains of carbon atoms that can be almost unlimited in length**
   b. **Carbon-carbon bonds can be single, double, or triple; carbon can also form rings of connected carbon atoms**

c. **Carbon can form millions of different structures, small to complex – this versatility is unmatched by any other element**

IV. Macromolecules

A. Macromolecule – "giant molecules" – made up of thousands or hundreds of thousands of smaller molecules

1. **Most macromolecules are built by joining smaller molecules together, a process known as polymerization**
2. **Monomers – "single part" – the small molecules being joined together to make up a polymer**
3. **Polymer – "many parts" – the larger molecules made from joining together monomers**
4. **Sometimes the monomers in a polymer are identical, sometimes they are different**

B. Macromolecules in living things are sorted according to their composition. There are 4 different macromolecules in living things – carbohydrates, lipids, nucleic acids, and proteins.

1. **Carbohydrates**
    a. **made up of carbon, hydrogen, and oxygen atoms, usually in a ration of 1:2:1 (2 for the hydrogen)**

b. **are the main source of energy for living things, but plants, some animals, and some other organisms use carbohydrates for structural purposes as well**
   i. **breakdown of sugars (like glucose) supplies immediate energy for cell activity**
   ii. **starches are carbohydrates used by many organisms to store extra sugar**

c. **monosaccharides: single sugar molecules such as glucose, galactose, fructose**

d. **polysaccharides: large molecules formed from monosaccharides; also called complex carbohydrates**
   i. **glycogen – aka "animal starch" – a polysaccharide, used to store excess sugar**
      - **glycogen is broken down into glucose when the glucose level drops in your blood**
      - **glycogen can be stored in the muscles and is used to power muscle contraction**
   ii. **starch: also a polysaccharide**

iii. **cellulose: additional polysaccharide used by plants**
   - **cellulose fibers are tough and flexible, giving plants both strength and rigidity; major component of wood and paper**

2. **Lipids**
   a. **made mostly of carbon and hydrogen atoms**
   b. **generally not soluble in water; include fats, oils, and waxes as major categories; steroids made by the body are also lipids**
   c. **used to store energy; some are also important components of waterproof coverings and biological membranes; steroids often function as chemical messengers**
   d. **many lipids are formed when a glycerol molecule combines with compounds called fatty acids (long chains of carbons bonded with many hydrogen atoms)**
   e. **classification:**
      i. **saturated – the fatty acids contain the maximum amount of hydrogen atoms (all single bonds between carbons)**
      ii. **unsaturated – at least one carbon-carbon double bond exists in the fatty acid (includes olive oil)**

iii. **polyunsaturated – more than one double bond is present in the fatty acid (includes corn oil, sesame oil, canola oil, peanut oil)**

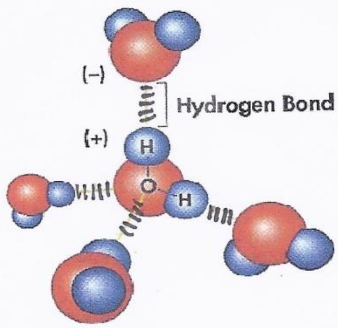
3. **Nucleic Acids**
    a. **contain hydrogen, oxygen, nitrogen, carbon, phosphorous**
    b. **they are polymers assembled from monomers called nucleotides, which are made of a sugar, a phosphate group, and a nitrogenous base**
    c. **store and transmit genetic information**
    d. **two main kinds – DNA (deoxyribonucleic acid) and RNA (ribonucleic acid)**

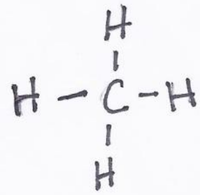
4. **Protein**
    a. **contain nitrogen, carbon, hydrogen, and oxygen**
    b. **they are polymers assembled from monomers called amino acids**
        i. **amino acids are compounds with an amino group (NH_2) on one end and a carboxyl group (COOH) on the other end**

ii. **amino acids are joined by covalent bonds (electrons are shared) called peptide bonds; amino acids joined together form a polypeptide**

iii. **a protein is a functional molecule built from one or more polypeptides**

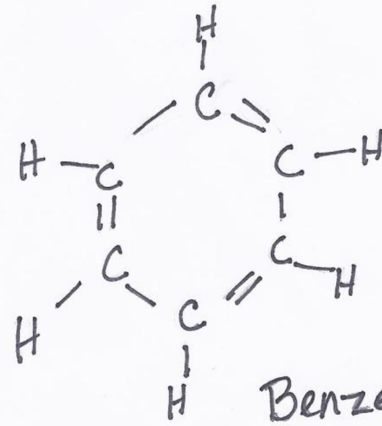
c. **proteins can control the rate of reactions (proteins that do this are called enzymes) and regulate cell processes; others form cell structures; others transport substances in and out of the cell; still others help to fight disease**





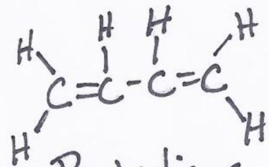
Methane

Acetylene

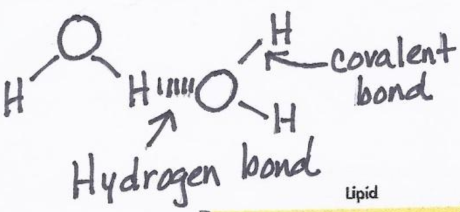


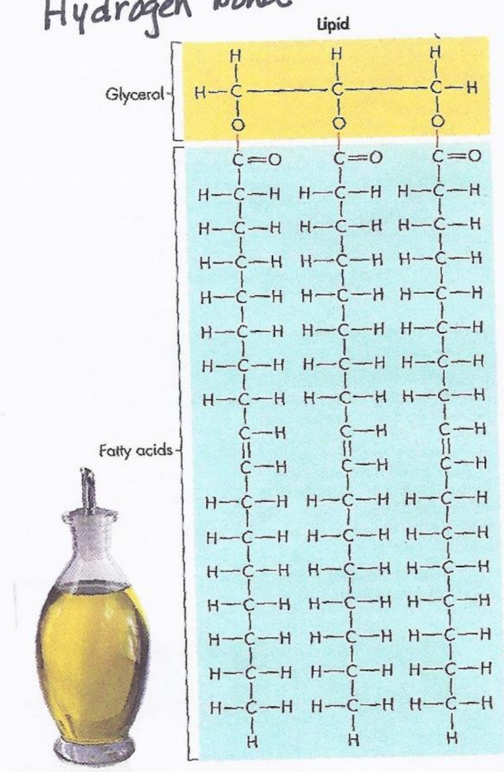
Benzene

Each molecule of water can form multiple hydrogen bonds with other water molecules.



Butadiene





Lipids are often made from a glycerol with fatty acids attached.

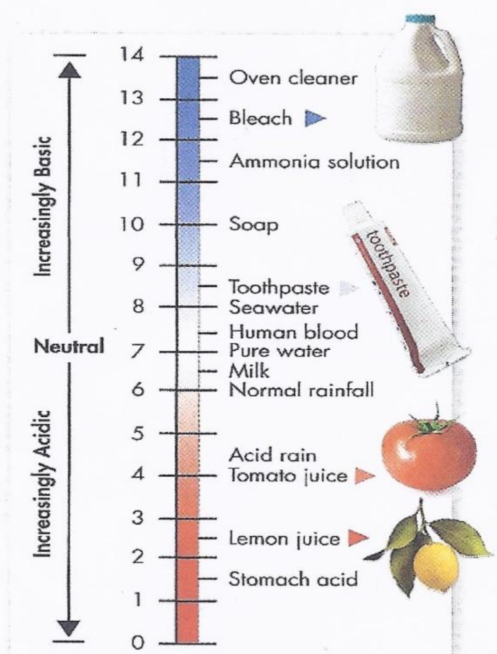


FIGURE 2–10 The pH Scale The concentration of H^+ ions determines whether solutions are acidic or basic. The most acidic material on this pH scale is stomach acid. The most basic material on this scale is oven cleaner.

I. Microscopes

A. Two main types

1. **light microscope: produces magnified images by focusing visible light rays**
2. **electron microscope: produce magnified images by focusing beams of electrons**

B. Two main problems in making microscopes

1. **What is the instrument's magnification?**
   a. **how much larger can it make an object appear than its real size?**
2. **How sharp an image can the microscope produce?**

C. Light Microscopes

1. **most commonly used**
2. **magnification is about 1000x**
3. **compound light microscope: allows light to pass through the specimen (what you're looking at) and uses 2 lenses to form an image**
   a. **can view dead organism and their parts**
   b. **can view some tiny organisms and cells while living**
4. **Methods to improve using a light microscope**
   a. **chemical stains to show specific structures in cells and other specimens**
   b. **using video cameras and computer processing to produce moving 3D images**
5. **Main advantages:**
   a. **very affordable**
   b. **easy to use**

6. **Main disadvantages:**
    a. **magnification is very limited**
    b. **images can often be grainy, poor quality**

D. Electron Microscopes

1. **primarily used to see extremely tiny objects**
2. **magnification is vastly greater than light microscopes**
3. **two main types of electron microscopes**
    a. **transmission electron microscopes (TEMs) - shine a beam of electrons through a thin specimen**

- **can reveal lots of detail inside the cell**
- **samples must be preserved and dehydrated (nothing living)**

    b. **scanning electron microscope (SEMs) – scans a narrow beam of electrons back and forth across the surface of a specimen**

- **produce realistic and detailed 3D images of the surfaces of objects**
- **the images are often quite surprising in their details**
- **like TEMs, samples must be preserved and dehydrated**

4. **Main Advantages**
    a. **pictures are spectacular**
    b. **the magnification is fantastic**

5. **Main Disadvantages**
    a. **extremely expensive**
    b. **need extensive training to use**

E. **In the 1990's, scientists perfected a new type of microscope, the scanning probe microscope.**
    1. **produces images by tracing the surfaces of samples with a fine probe**
    2. **now possible to view single atoms**
    3. **can operate in ordinary air (SEMs and TEMs need a vacuum) and can show samples in solution**
    4. **revolutionizing what and how we study many small particles**