Biology 1.4
Scientific Method and tools

Created with senses and a rational mind, we are capable through observation, interpretation, and experimentation of seeing, understanding, and confirming truths about creation and God.

A. The scientific method

1. Observation
2. Interpretation
3. Experimentation

B. Observation

1. Quantifiable measurements of everything observed makes empirical descriptions useful. Therefore, math is important to describing creation and is the language of science.
2. Units of measurement in science
   a. The metric system
   b. Size/distance measurements
      i. Kilometer: 1,000 meters
      ii. Decameter: 10
      iii. Meter: 1 yard 3 inches 1
      iv. Decimeters: 0.1
      v. Centimeter: 2.54 cm = 1 inch 0.01
      vi. Millimeter: 0.001
      vii. Micrometer: 0.0000001
      viii. Nanometer: 0.0000000001
      ix. Angstrom 0.00000000001
   c. Volume: Liter
   d. Weight/mass: Gram
   e. Temperature: Celsius or Kelvin
   f. Energy: Joule
   g. Electric current: Ampere
   h. Loudness of sound waves: Bel
   i. Time: Seconds
   j. Luminosity: candela
   k. Hardness of materials, etc

C. Tools of quantification in science

1. Counters- quantifies the number of items.
2. Ruler- quantifies length.
3. Ohmmeter/ammeter- quantifies resistance and flow of electrons.
4. Oscilloscope- quantifies sound.
5. Spectrophotometer- quantifies color of light.
6. Stop watch- quantifies the lapse of time.
7. Thermometer- quantifies temperature.
8. Hygrometer- quantifies moisture (humidity) in the air.
9. Barometer-quantifies atmospheric pressure.

D. The light Microscope

1. Life is made of cells, so magnification is essential to the study of life.
2. Visual tool that enables us to see things that are too small with the naked eye.
3. Living things are made of cells, so magnification is essential to the study of life.
4. Anton van Leeuwenhoek- Father of microscopy
5. Microscope specialist. Made over 200 lenses
6. Simple microscope: one lens
7. Compound microscope: two or more lenses
8. More than one lens (Janssen Brothers)
9. Double magnification.
10. Second lens magnifies the first image.
11. Monoscopic: one or two eyepieces. One image, same angle of vision.
12. Stereoscopic: two eyepieces. Two angles of vision combined into one image. Allows depth perception. Often used for dissections. Usually lower magnification.
13. Eyepiece (Ocular): first lens thought which one looks.
14. Objectives: vary in magnification
15. Typical compound scope has three or four objective lenses.
16. Revolving nosepiece: holds objective lenses
17. Stage: Holds specimen
18. Body tube: Space between objective lenses and ocular
19. Focusing knobs: coarse adjustment and fine adjustment
20. Light source: Illuminator/mirror
21. Diaphragm: adjusts amount of light
22. Sub stage condenser: focuses the light into the specimen. No magnification

E. The electron microscope

1. Uses electrons instead of light waves. Much smaller amplitude gives much greater resolution.
2. Vacuum stage is required.
3. Specimens must be very thin (e.g. 300 angstroms)
4. Specimens are treated with electron-dense stains
5. Electromagnets are used to focus beam
6. Electron micrographs capture the image like a photo for viewing.
7. Scanning electron microscope: shows surface structures of specimen.
8. Transmission electron microscope transmits a beam of electrons through a specimen.

F. Magnification Principles (Demonstration)

1. Reflection of light enables us to see
2. Refraction: the bending of light waves
3. Resolution: The ability to distinguish detail (e.g., Hubble scope, two lines)
    a. Limited by the amplitude of photon or electron wave

G. Chemical analysis

1. Stains and dyes: react with different molecules in cells.
2. Cell fractionation: Isolate structures by breaking cells, and then centrifuging.
3. Autoradiography: Radioactive elements absorbed by cells and detected by electron microscope

H. Validity limitations of biological studies

1. Accuracy of tools

2. Technique to collect accurate measurements
3. Integrity and typicalness of Specimen.
4. Experimental design
5. Interpretation skills

I. Math (calculating numbers) is the language of science

1. Multiply the lens power of each lens used (e.g. 10x40=400)
2. Oil immersion lenses: 100x or 120x with a 10x ocular magnify to 1,000 or 1200 times.
3. How many subatomic particles in a 50 gram hamster?
4. How small is a cell?
5. How many molecules of insulin are produced in the human body every day?

J. Interpretation

1. Logical thinking: inductive and deductive
2. Models
    a. Explanations of how things, observed and measured, work.
    b. Most descriptions of the world are models: light, atom, evolution, creation
    c. Used to explain the known data and predict the unknown. Sometimes two or more models explain the same phenomena: e.g., light wave/particle; cellular versus chemical immunity.
    d. Subject to change as more information is discovered.
    e. Models are the best way to deal with the unknown. However, personal and political bias can lead to faulty conclusions.
3. The making of scientific laws
    a. Hypothesis
    b. Theory
    c. Law

K. Experimentation

1. Test explanation and predictions
2. Design to accurately simulate real world conditions.
3. Ethical considerations require animal tests before human tests. *in vitro* then *in vivo*.
4. Single variable **control** comparison makes deduction possible.
5. Repetition makes induction possible.

L. Preparing an experiment

1. Ask a question. Think of something you are curious about. Look around your school or home, consider your hobbies, identify problems needing to be fixed, listen to questions others ask, etc.
2. Read articles to find an answer to your question, or to find more questions being asked.
3. Propose a hypothesis, which is an explanation to your question. Read more about the topic and talk to others about it. Determine if this is something you can do (time, tools, money).
4. Write a proposal, and submit completed forms for your experiment to the scientific review committee.

M. Standard scientific reporting includes:

1. Introduction:
    a. State the question or problem to study.

    b. State your interpretation as a hypothesis to define your variable and experiment.
    c. State the reason for your hypothesis.
2. Materials and method
    a. Describe specific details about the materials needed for the experiment.
    b. Describe the technique used to conduct the experiment.
    c. Describe the measurements and tools used to collect data.
3. Results
    a. Organize the data in a meaningful way to show patterns and trends.
    b. Describe the data collected from the experiment.
4. Conclusion
    a. Explain what conclusion can be made from the results.
    b. Discuss how the conclusion compares to the findings of others'.
    c. Propose additional questions to be answered and explain why they are relevant to your experiment.
5. Abstract
    a. Summarize the introduction, method, results, and conclusion into a brief paragraph.