BIOLOGICAL SCIENCE

Notebook

ROY W. JONES and I. E. WALLEN

BIOLOGICAL SCIENCE NOTEBOOK

A guide for lecture and laboratory notes in Biological Science

by

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PREFACE

The notebook is an outgrowth of a cooperative study conducted by the staff of the Biological Science Course and the faculty committee on General Education in the School of Arts and Sciences at Oklahoma A. & M. College. The committee on general education has for the last six years been exploring the view expressed by Dean Schiller Scroggs that a satisfactory program in general education must be constructed around a few "key concepts" which not only integrate and unify the subject material but also influence the value judgments and the social responses of the students participating in the program.

The Biological Science Course at Oklahoma A. & M. College was organized in 1935 under the direction of a faculty committee from the various biological disciplines or departments in the School of Arts and Sciences. The course developed under the direction of several individuals until taken over by Professor R. O. Whitenton, then Head of the department of Zoology. Under his direction a terminal course in biology was developed for those students who did not expect to be professional biologists.

Upon the foundations established by Professor Whitenton and the committee, the present course evolved. It is <u>not</u> a basic course required of all students. It is a two semester, eight hour course consisting of: three lectures per week, one-discussion-demonstration (laboratory) period per week, and an hour each week devoted to: films, examinations, and invited lectures by selected individuals outside of the regular Biological Science staff.

In cooperation with students in the classes and the members of the committee on general education, the Biological Science staff has formulated the following list of "key concepts" about which the course has been organized.

1. The cell is a unit of structure and function in any individual, although the individual may be more than a sum of its parts. (That is, more value may be attached to arrangement than simple anatomical structure might suggest).

2. Any living plant or animal consisting of one cell, or many cells, demonstrates the organizational attributes of an individual.

3. Food manufacture by green plants is basic to all life on earth in converting energy from light into food.

4. The food that we eat is relatively complex in structure and must be digested to smaller particles and absorbed before it becomes available for our use.

5. Energy is released for biological activities only through combination with oxygen so that a supply of oxygen must be secured and waste gases must be eliminated.

6. The principle of levers applies in animal movements by the use of muscles, bones and joints.

7. Some biological wastes are toxic and must be removed by special organs.

8. Complex transporting systems are necessary to supply the body needs for food and oxygen and to remove waste products from the cells.

9. Mechanisms for response to stimuli exist of two types (chemical and nervous) and these regulate and coordinate the body functions.

10. Reproduction is a biological function normal to all organisms and may require special structures.

11. Organisms of every type reproduce their kind by means of unit characters (genes) that segregate and recombine to provide individual variations.

12. Organisms exist with life characteristics of many kinds, but these organisms may be arranged into groups of species related by their similarities, and separated by their differences.

13. Life is dependent upon the establishment of successful relationships between organisms of the same and different types and their respective environments.

14. Changes have taken place in the composition and relationships of animals and plants since life first existed. Man's attempts to explain these changes have profoundly influenced his thought.

15. It is a duty of all citizens to conserve their biological resources (human, plant, and animal) if these resources are to properly serve human needs.

16. Biological information is the only sound basis for any program related to public health.

17. Most social problems are biological and recognition of this fact will assist us in our search for answers.

In an attempt to keep the various sections of the course somewhat uniform so that single tests, grading curves, etc. might be used, it was found desirable to develop an outline or guide for the use of the instructors. This outline was expanded into mimeographed, one page, lecture outlines for student use. The students found these guides so useful that they requested that they be developed and published in book or pamphlet form and made a part of the textbook or resource material. This is our attempt to meet that request.

We want to acknowledge our debt to the various individuals who have contributed to the "Bi. Sci." course in the past: H. I. Featherly, G. J. Ikenberry, O. C. Schultz, H. W. Orr, W. H. Irwin, J. C. Howell, Mrs. Helen Stocking, Hunter M. Hancock, R. M. Chatters, Imy Holt, et. al. Especially, do we wish to recognize Professor R. O. Whitenton who has guided the Bi. Sci. course for many years and whose advice and counsel we respect most highly.

For all errors and omissions we accept full responsibility.

Roy W. Jones

I. E. Wallen

INTRODUCTION (HOW TO USE)

The following outlines are intended to help students prepare assignments in Biological Science and to assist them in taking notes in lectures and laboratory. It will be necessary for students to consult source material and textbook references to learn the meanings of terms and to understand the details of explanations. The purpose of these notes is to assist the student in organizing the subject matter of a topic and in recognizing the essential information necessary to an understanding of it.

It is suggested that students use the following procedure: 1. Consult the textbook or a reference book containing material on the topic and quickly scan the chapters or units concerned. 2. Then, read the portions associated with the various parts of the outline in detail, noting especially vocabulary and relationships to other ideas. If necessary, supplement or revise the outline by notes in the margin or on the page opposite. It is better to read several references on a topic than to try to memorize one. It is concepts or understandings that we are striving for rather than memorization. 3. During lectures, note on the blank page opposite the outline the new terms, ideas, or points emphasized. One can thus pay attention to the development of ideas and concepts as presented by the instructor instead of frantically trying to write down what he says without appreciating its meaning or significance. 4. In reviewing for a test, one can check the outlines and supplementary notes, determine what areas are <u>least</u> understood and most important and concentrate on their mastery.

At Oklahoma A. & M. College students will be issued at the beginning of each semester a calendar of topic assignments with specific textbook references. The lectures will follow the calendar assignments. In some semesters, therefore, some of the outlines included herein will be omitted and in other instances two or more of the topics may be covered in one lecture or laboratory period.

REFERENCES

There are many excellent textbooks in the field of Biological Science. Some of them are listed here. It is hoped that students will consult the card index in the library for supplementary references in specialized texts on specific topics. It is also hoped that many students will form the habit of keeping abreast of current developments by regularly reading the science sections in such periodicals as: Life, Time, Newsweek, etc. and by browsing in such journals as: The Scientific American, Science News Letter, Science, The Scientific Monthly, Hygeia, The Journal of Heredity, Nature, The American Scientist, etc.

Recent Textbooks for Biological Science:

1. de Laubenfels, M. W., 1949, "Life Science", 4th edition, Prentice-Hall.
2. Elkin, William, 1950, "College Biology", Thomas Y. Crowell Company.
3. Gardiner, Mary S., 1952, "The Principles of General Biology", Macmillan Co.
4. Harbaugh, et al., 1953, "Fundamentals of Biology", Blakiston.
5. Hardin, Garrett, 1952, "Biology, Its Human Implications", Second edition, W. H. Freeman Company.
6. Jean, Harrah, Herman and Powers, 1952, "Man and His Biological World". Revised edition. Ginn and Company.
7. Kenoyer, Goddard, and Miller, 1953, "General Biology", 3rd edition, Harper.
8. Marsland, 1951, "Principles of Modern Biology", Henry Holt.
9. Mavor, James Watt, 1952, "General Biology", 4th edition, Macmillan.
10. Milne, Lorus J. and Margery J., 1952, "The Biotic World and Man", Prentice Hall.
11. Moment, Gairdner B., 1950, "General Biology", Second edition, Appleton-Century.
12. Pauli, Wolfgang F., 1949, "The World of Life", Houghton Mifflin.
13. Rogers, Hubbell, and Byers, 1952, "Man and the Biological World", 2nd edition, McGraw-Hill.
14. Stanford, E. E., 1951, "Man and the Living World", second edition, Macmillan.
15. Stauffer, et. al., 1954, "Introductory Biology", 2nd edition, Van Nostrand.
16. Strausbaugh and Weimer, 1952, "General Biology", 3rd edition, Wiley.
17. Villee, Claude A., 1954, "Biology", 2nd edition, W. B. Saunders.
18. Weisz, Paul B., 1954, "Biology", McGraw-Hill.
19. Whaley, et. al., 1954, "Principles of Biology", Harper and Bros.
20. Winchester, A. M., 1949, "Biology and Its Relation to Mankind", D. Van Nostrand.
21. Woodruff and Baitsell, 1951, "Foundations of Biology", Macmillan Co.
22. Young and Stebbins, 1951, "The Human Organism and the World of Life", Revised edition, Harper.

A list of Special lecture topics that have been presented

1. Science and the Scientific Method.
2. Recent trends in the Field of Psychology.
3. The Genetics of Microorganisms.
4. Applications of Genetics.
5. Tracking Tornadoes.
6. What makes Weather?
7. Oklahoma Flowers.
8. Birds of Oklahoma.
9. Applications of Taxonomy: Fishes of Oklahoma.
10. The Plant Kingdom.
11. The Geological History of the Earth.
12. Chemistry in Biology.
13. The Philosophy of Conservation.
14. Recent Advances in the Field of Medicine.
15. Science and Religion.
16. The Control of Insect Pests.

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Lecture #1 **WHAT IS BIOLOGY ?**

I. BIOLOGY IS THE STUDY OF LIVING THINGS.
   A. "Bios" - life and "Logos" - study of.

II. BIOLOGY INCLUDES THE STUDY OF PLANTS AND ANIMALS.
   A. Botany - the study of plants.
   B. Zoology - the study of animals.

III. BIOLOGY CAN BE DIVIDED INTO STUDIES OF:
   A. Morphology - form and structure.
   B. Physiology - function.

IV. DISTINGUISH BETWEEN BEING "ALIVE" AND "DEAD".
   A. What are the "distinguishing characteristics" of living matter (protoplasm)?

V. HOW CAN WE RECOGNIZE PLANTS FROM ANIMALS?
   A. Is the phenomenon of "life" similar in plants and animals?
   B. Is the phenomenon of "life" in man similar to that in other animals?

VI. WHAT DO YOU WANT OR EXPECT TO LEARN IN THIS COURSE?

VII. SOME OBJECTIVES OF A COURSE IN BIOLOGICAL SCIENCE.
   A. Development of an interest in natural phenomena.
   B. Development of an appreciation of the orderliness in nature.
   C. Recognition of man's place in the world of living things.
   D. Development of an appreciation of the technique, uses, and limitations of the "Scientific Method".
   E. How to read and evaluate articles and news stories on science in the current literature.

VIII. THE CONTENTS OF THIS COURSE.
   A. First Semester - The biology of the individual: fundamental functions or activities characteristic of life; how can we assist our bodies in performing these functions?
   B. Second Semester - The biology of the race: heredity; taxonomy or the kinds of living things; ecology or the effects of and on the environment; evolution or development; applications or how we use the principles of biology in everyday living; problems of survival.

IX. THE BIOLOGICAL SCIENCES.
   A. Morphology - form.
      1. Anatomy - gross structure.
      2. Histology - microscopic structure.
   B. Physiology - function.
   C. Pathology - disease.
   D. Hygiene - care.
   F. Taxonomy - classification.
   F. Genetics - heredity.
   G. Ecology - habitats or homes.
   H. Embryology - development of the individual.
   I. Psychology - behavior.
   J. Sociology - relationships.
   K. Special fields - Cytology, Entomology, Bacteriology, Parasitology, Ichthyology, Virology, etc.
   L. Applied biology - Medicine, Agriculture, Forestry, etc.

X. DISCUSSION.
   A. What is man's place in the universe?
   B. Are all human problems biological?
   C. What do we mean by: a science? a scientist? being scientific?

Lecture #2 THE CHEMICAL NATURE OF PROTOPLASM

Atomic and Molecular Structure

I. COMPOSITION OF MATTER: - MASS - UNITS OF VARIOUS KINDS.
   A. Atoms, molecules, compounds, elements, acids, bases, salts, colloids, crystalloids, emulsions, solutions, solvent, solute, ions.

II. STATES OF MATTER: - GAS, LIQUID, SOLID, COLLOIDAL.
   A. Differences in molecular motion.

III. ENERGY - ULTIMATELY, MASS IN MOTION.
   A. Forms of energy: potential, kinetic, mechanical, heat, electrical, chemical, light, atomic.

IV. LAW OF CONSERVATION OF MATTER AND ENERGY.

V. PROPERTIES OF MATTER: REACTS TO FORM TEMPORARY OR PERMANENT UNIONS.
   A. Chemical symbols, formulae, and equations.
      1. C. HOPKINS Ca Fe Mg.; H_2O, H_2SO_4, $C_6H_{12}O_6$,
         $6CO_2 + 6H_2O \rightleftharpoons C_6H_{12}O_6 + 6O_2$.

VI. CLASSES OF COMPOUNDS FOUND IN PROTOPLASM - <u>ORGANIC</u> AND <u>INORGANIC</u>.
   A. Carbohydrates - C H_2O
   B. Fats - C H O
   C. Proteins - C H O N ?
   D. Water - Universal solvent ?
   E. Mineral Salts - Na, Fe, Ca, SO_4, NO_3, Cl, etc.

VII. COLLOIDS - NATURE AND PROPERTIES.

VIII. COMPOSITION OF PROTOPLASM.
   A. Not a distinct compound - no empirical formula.
   B. A mixture of compounds and colloids in water. Definition?
   C. The properties of a substance are not equal to the sum of the properties of the elements or compounds contained therein, but are due to the organization of substance itself, therefore, are peculiar to that substance.

   D. Life vs. Death. Discussion.

IX. DISCUSSION:
   A. Would life be possible without reversible or cyclic chemical reactions?
   B. In what ways do living cells differ from machines?
   C. What does "an organism" mean?
   D. When is an animal dead? a plant?
   E. Does all life come from pre-existing life?

Lecture #3 THE CELL

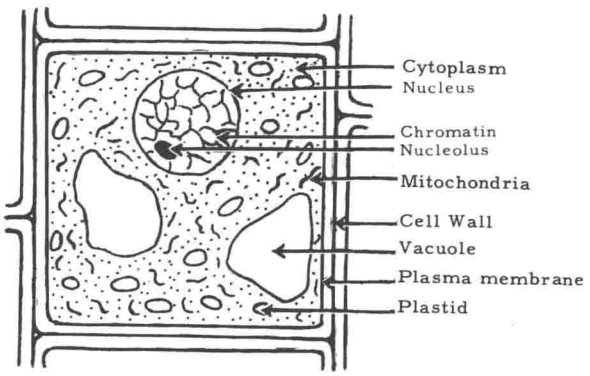
I. THE VISIBLE STRUCTURE OF AN ORGANISM.
   A. Recognition that there is specialization of functions.

II. HISTORY OF THE CELL PRINCIPLE.
   A. Jensen - 1591 - microscope.
   B. Leeuwenhoek - 1632-1723 - Using the microscope.
   C. Hooke, Robert - 1665 - Cork - "cells".
   D. Brown, Robert - 1833 - "nucleus".
   E. Schleiden and Schwann - 1838-39 - cell - unit.
   F. Schultze - 1861 - Protoplasm - living material.

III. MODERN CONCEPT OF THE CELL DOCTRINE.
  A. "All plants and animals - living matter - are made up of or are organized into units called cells. The cell is the structural and functional unit of all protoplasm."

IV. THE IMPORTANCE OF THIS CONCEPT.
  A. Basic to embryology, histology, genetics, physiology, pathology, etc.

V. THE STRUCTURE OF A TYPICAL CELL.
  A. Cell wall - living?
  B. Protoplasm.
    1. Plasma membrane - cellular exchange.
    2. Cytoplasm - plastids, vacuoles, centrisome, mitochondria, Golgi body.
    3. Nucleus - membrane, sap, nucleolus, chromosomes, chromatin.



Generalized
PLANT CELL

VI. KINDS OF CELLS - VARIATIONS IN SIZE, SHAPE, STRUCTURE, FUNCTION.
  A. Intra- and inter-cellular specialization.
  B. Syncytium.

VII. DISCUSSION:
  A. Why is the cell doctrine considered basic to modern biology?
  B. What part of the cell is the source of its life?
  C. Define "a cell" in the biological sense.

Lecture #4 THE DIFFERENTIATION AND SPECIALIZATION OF CELLS

Tissues, Organs - The Organism

I. UNICELLULAR OR NON-CELLULAR SPECIALIZATION.
  A. Description of an Ameba and a Paramecium: comparison to behavior of a horse as seen from an airplane.
  B. Protozoa and Protista.
  C. Acellular?

II. MULTICELLULAR SPECIALIZATION - COLONIAL THEORY.
  A. Probable origin of multicellular forms.
    1. Colonies - spherical, linear, plate-like, branching.
    2. Differentiation of somatic cells from germ cells.

III. THE ORGANISMAL THEORY - WHAT IS AN INDIVIDUAL ORGANISM?

IV. CAUSES OF CELLULAR DIFFERENTIATION - EMBRYOLOGY.
  A. Position, function, organizers, genes.

V. TYPES OF TISSUE. (WHAT IS A TISSUE?)
  A. Animal.
    1. Epithelial - membranes - substances go in and out.
      a. Squamous, columnar, cuboidal, stratified, glandular.
    2. Sustentative - supporting or connecting.
      a. Cartilage, bone, connective, ligaments, tendons, vascular.
    3. Muscle - contractility and elasticity.
      a. Smooth, striated, cardiac - nerve supply, cell structure.
    4. Nervous - conductivity.
    5. Embryonic or germinal - cellular proliferation.

B. Plant.
   1. Simple.
      a. Meristem - apical, lateral, cambium.
      b. Permanent or differentiated:
         (1) Parenchyma, chlorenchyma, collenchyma, sclerenchyma, epidermal (cutin), cork (subrin).
   2. Complex.
      a. Xylem - tracheids, vessels - water.
      b. Phloem - sieve tubes, companion cells - food - roots and stems.
      c. Fibro-vascular bundles - monocots and dicots.

VI. ORGANS AND SYSTEMS - PLANT AND ANIMAL.

VII. DISCUSSION:
   A. What advantages and disadvantages does a multicellular organism have over a uni-cellular?
   B. What is the chief difference in their modes of life which requires most animals to be mobile, whereas most plants are stationary?
   C. How do we know when someone is dead?
   D. Discuss the organization of an individual.

Lecture #5 THE PHYSIOLOGY OF PROTOPLASM

Cellular Exchange

I. METABOLISM: ANABOLISM VS. CATABOLISM.

II. FUNDAMENTAL FUNCTIONS OF LIFE.
   A. Photosynthesis - storage of sun's energy.
   B. Nutrition:
      1. Ingestion.
      2. Digestion (and secretion).
      3. Absorption.
      4. Assimilation.
   C. Circulation (transportation)
   D. Respiration.
   E. Excretion.
   F. Irritation or irritability:
      1. Receptors - sense organs.
      2. Effectors - muscles, glands.
   G. Coordination:
      1. Chemical.
      2. Neural.
   H. Growth.
   I. Reproduction

III. CELLULAR EXCHANGE.
   A. Molecular motion: diffusion, solution, imbibition.
   B. Differentially permeable membranes - living and dead.
   C. Osmosis and dialysis - solute and solvent - osmotic pressure.
   D. Turgor, plasmolysis - addition and removal of water from cells.
   E. Surface tension phenomena.
   F. Colloids, emulsions, crystalloids.

IV. DISCUSSION:
   A. How could you determine experimentally whether a given substance can penetrate a red blood cell membrane?
   B. Define diffusion and osmosis.
   D. Why are colloids so important in cellular exchange?

Lecture #6 THE ANATOMY OF A FLOWERING PLANT:

Roots and Stem

I. THE ORGANIZATION OF AN INDIVIDUAL PLANT. (ANGIOSPERM)
- A. Organs and systems.
- B. Basic divisions of a plant.
  1. Roots - functions, types.
  2. Stems - functions, types.
  3. Leaves - functions, types.
  4. Flowers - functions, parts.
  5. Fruits - functions, structure, types.
  6. Seeds - functions, structure, types.
- C. Systems.
  1. Vascular.
     - a. Water-conducting - xylem.
     - b. Food-conducting - phloem.
  2. Photosynthetic - chlorophyll.
  3. Respiratory - stomata.
  4. Absorbing - root hairs.
  5. Storage.
  6. Excretory.
  7. Sensory.
  8. Glandular.
  9. Integumentary.

II. THE ROOT.
- A. Primary xylem and phloem.
- B. Secondary xylem, cambium, and phloem.
  1. Monocots and dicots.
- C. Root hairs.
- D. Types - tap, fibrous.
- E. Growth.

III. THE STEM.
- A. Nodes, internodes, annual rings.
- B. Monocots and dicots.
- C. Xylem, cambium, phloem.
- D. Special types - rhizomes (Iris), tuber (potato), stolon (strawberry), thorns (honey locust).
- E. Functions.

IV. DISCUSSION.
- A. How can you tell a stem from a root?
- B. How can you tell monocots from dicots?
- C. What is the advantage to a plant in having its growing region near the top of the stem rather than near the base?
- D. Why do young trees die when the bark is gnawed by rabbits?

Lecture #7 PLANT ANATOMY (CONTINUED)

The Leaf

I. STRUCTURE OF A TYPICAL LEAF - CROSS-SECTION.
- A. Epidermis - stomata, guard cells - cuticle, hairs.
- B. Pallisade cells (photosynthesis) - chlorenchyma (chlorophyll).
- C. Spongy tissue or parenchyma.
- D. Vascular systems - veins.
  1. Venation - Monocot, Dicot.
  2. Xylem and phloem.

II. FUNCTIONS OF LEAVES.
- A. Photosynthesis - discussed in detail later.
- B. Transpiration - importance.
- C. Excretion.
- D. Food storage.
- E. Reproduction.

III. KINDS OF LEAVES.
- A. Monocot vs. Dicot.
- B. Margins.
- C. Leaf buds.

IV. DISCUSSION.
- A. How does water get up to the top leaves of tall seed plants (trees)?
- B. Why do we remove most of the leaves from a plant when we transplant it?
- C. How many plants can you name whose leaves are used for human food? What food substances do they furnish?
- D. How are leaves modified to decrease transpiration?
- E. What process occurs in the leaf upon which all life as we know it depends?

Lecture #8 PHOTOSYNTHESIS - THE MAKING OF FOOD

I. PHOTOSYNTHESIS - PHOTO-LIGHT; SYNTHESIS - TO PUT TOGETHER.
- A. What is photosynthesis?
  1. Sun's energy.
- B. Where does it occur?
  1. Only in green plants (chlorophyll).
- C. Why is it so important?
  1. Source of energy - and food.

II. FACTORS OR FORCES NECESSARY IN ORDER FOR PHOTOSYNTHESIS TO OCCUR.
- A. Chlorophyll - proof?
- B. Light - proof?
- C. Water - proof?
- D. Carbon dioxide - proof?

III. COMPARISON OF PHOTOSYNTHESIS AND RESPIRATION.
- A. Light energy + $6CO_2 + 6H_2O \rightleftharpoons C_6H_{12}O_6 + 6O_2$.
- B.

Photosynthesis	vs.	Respiration.
1. Only in light.		everywhere.
2. Energy stored.		energy released.
3. $H_2O + CO_2$ consumed.		released.
4. O_2 released.		consumed.
5. Carbohydrates formed.		consumed.
6. Weight of plant increased.		decreased.

IV. STORAGE VS. TRANSLOCATION.
- A. Structure of carbohydrate molecules -
- B. Mono-, di-, and polysaccharides - solubility and dialysis.
- C. Hydrolysis of polysaccharides - $(C_6H_{10}O_5)n + n(H_2O) \longrightarrow n(C_6H_{12}O_6)$.
  starch water sugar

V. PLANT METABOLISM.
- A. Sources of CO_2 and H_2O - atmosphere, xylem, phloem, stomata, lenticels.
- B. Synthesis of other materials - proteins, fats, vitamins, etc.
- C. Chlorophyll - constituents - Mg, Fe.
  1. $C_{55}H_{72}O_5N_4Mg$ - A.
  2. $C_{55}H_{70}O_6N_4Mg$ - B.
  3. Replace Mg with Fe (Iron) $\longrightarrow$ "heme".
     heme + protein $\longrightarrow$ hemoglobin (red coloring matter of the blood)
     chlorophyll + protein $\longrightarrow$ chloroplastid compound
  4. Iron necessary for synthesis of both hemoglobin and chlorophyll.

VI. METABOLISM - PLANT VS. ANIMAL.
- A. Synthesis occurs — very limited
- B. Independent — dependent
- C. Absorbs nutrients in solution — ingests solid food
- D. Catabolism less — catabolism more (locomotion)
- E. Energy from light? — energy from organic foods

VII. CHEMOTROPIC NUTRITION OF BACTERIA - ENERGY FROM INORGANIC OXIDATION.

VIII. DISCUSSION:

A. What is the significance of photosynthesis?

Lecture #9 FOOD SUBSTANCES

Their Composition and Functions

I. FOODS.
- A. Definition - "Substances which furnish a living organism energy, or materials for growth and/or repair, or act as catalysts."
- B. Classes of foodstuffs.
  1. Carbohydrates - CH_2O - 'ose.
     - a. Monosaccharide - simple or single - glucose or dextrose, $C_6H_{12}O_6$.
     - b. Di-saccharides - double sugar - sucrose (table), lactose (milk), maltose (malt).
     - c. Poly-saccharides - starch, glycogen, cellulose, etc., $(C_6H_{10}O_5)n$.
     - d. Functions - energy foods, temporary storage.
  2. Lipoids, lipins, lipids - fats, oils.
     - a. Fatty acids and glycerol - "ester".
       (1) May be synthesized by both plants and animals from excess sugars.
     - b. Functions - energy, storage, solvents.
  3. Proteins - "condensation products of amino-acids."
     - a. Amino acids - NH_2 and COOH - 22 kinds synthesized by plants.
     - b. Kinds of proteins -
       (1) Simple, conjugated, complex.
       (2) Characteristic of species and tissue.
     - c. Functions - construction, repair, maintenance, energy.
  4. Minerals -
     - a. Salts of Ca, Fe, I, Na, K, and Cl; SO_4, NO_3, PO_4, S, CO_3.
     - b. Chemical regulators.
  5. Vitamins - enzymes and/or catalysts (to be studied in detail later).
  6. Water - universal solvent? - major constituent of protoplasm.

II. ENERGY.
- A. Definition - kinds - potential, kinetic, chemical, atomic, electrical, mechanical, light, thermal.
- B. Calorie - "Cal" - energy to raise the temperature of 1 kg. of H_2O 1° C. (Centigrade vs. Farenheit)
- C. Human requirements.
  1. Minimum - 1600 Cal., Average - 2400-5000 Cal. dependent on physical condition and activity.
  2. 1 gm. Carbohydrate or protein = 4 Cal.
  3. 1 gm. fat = 9 Cal. = $2\frac{1}{4}$ X above
- D. Ultimate source = photosynthesis.

III. NUTRITION - THE INTAKE OF FOODS, THEIR CONVERSION AND USE.
- A. Types: Holophytic (plant), Holozoic (animals), Saprophytic (molds, etc.).