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AUTHOR Rasmussen, Ray S.
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ABSTRACT

This unit of instruction provides a laboratory oriented study of the chemical reaction involved in the life processes. Students enrolling in this course should have successfully completed the units on Scientific Mathematics, Introduction to Chemistry, Reactions of Atoms and Molecules, and Chemistry of Carbon and Its Compounds. The booklet lists texts recommended as student references and states the performance objectives for the unit. It provides an outline of the course content and suggests special laboratory procedures, laboratory experiments, and appropriate readings from a variety of books and periodicals. Also listed are relevant films available from the Dade County Audiovisual Center and other sources. A master sheet is provided relating each suggested activity to the specific performance objectives. (JR)

5E

AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

BIOCHEMISTRY

5317.66

SCIENCE

(Experimental)

DADE COUNTY PUBLIC SCHOOLS

DIVISION OF INSTRUCTION • 1971

BIOCHEMISTRY

5317.66

SCIENCE

(Experimental)

Written by Ray S. Rasmussen
for the
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2210 S. W. Third Street
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BIOCHEMISTRY

COURSE DESCRIPTION

In depth study of the chemical reactions involved in the life processes.

ENROLLMENT GUIDELINES

Students should have successfully completed Scientific Mathematics, Introduction to Chemistry, Reactions of Atoms and Molecules, and Chemistry of Carbon and Its Compounds, or show readiness by passing a test. The course is laboratory oriented and students should be adept at assembling and setting up equipment.

RECOMMENDED STUDENT REFERENCES

1. Allinger and Allinger. Structure of Organic Molecules. Englewood Cliffs, New Jersey: Prentice-Hall, 1965.

2. Baker and Allen. Matter, Energy and Life. Atlanta: Addison-Wesley, 1965.

3. Barker. Organic Chemistry of Biological Compounds. Englewood Cliffs, New Jersey: Prentice-Hall, 1965.

4. McElroy, W. D. Cell Physiology and Biochemistry. 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, 1964.

PERFORMANCE OBJECTIVES

The student should be able to:

1. Demonstrate an understanding of the material presented in Organic Chemistry Course Number 5317.65.

2. Diagram the dehydration syntheses of sugars, fatty acids, glycerol, and amino acids.

3. Demonstrate how large molecular units of carbohydrates, fats and proteins are built up by dehydration synthesis.

4. Illustrate how the peptide and polypeptide bonds in protein synthesis are the result of dehydration.

5. Show how hydrogen bonding and peptide linkage are used in the construction of all proteins.

6. Explain why the essential amino acids are called "essential".

7. Diagram the hydrolysis of carbohydrates, fats and proteins to simpler and smaller molecules.

8. Demonstrate the specificity of enzymes.

9. Demonstrate that enzymes work most efficiently at certain optimum temperatures.

10. Define substrate: (1) That the substance upon which the enzymatically controlled reaction occurs is called the substrate. (2) That the substrate for the enzyme sucrase is sucrose; for lactase, it is lactose; for trypsin, proteins.

11. Explain why glucose is an energy rich compound.

12. Demonstrate, by use of a diagram, the steps by which the glucose molecule is broken down, bit by bit, with small amounts of energy being released at each step, rather than all at once.

13. Explain the role of nucleic acids in the synthesis of proteins.

COURSE OUTLINE

I. Review of Basic Chemistry

A. Acids, bases and neutralization

1. pH

2. Buffer systems

B. Organic compounds

1. Functional groups

2. Hydrogen bonding

3. Dipolar charges and delta notation

II. Fundamental Organic Substances in Living Material

A. Carbohydrates

1. Types

a. Sugars, monosaccharides

(1) Pentoses - ribose, deoxyribose, xylose, arabinose
(2) Hexoses - glucose, fructose, galactose

b. Sugars, disaccharides

(1) Lactose
(2) Maltose

c. Sugars, polysaccharides

(1) n-number of monosaccharide units, called starches
(2) Starch, glycogen, dextrins, cellulose, mucilage

2. Chemical characteristics of carbohydrates

a. Formation of disaccharides and polysaccharides - dehydration synthesis
b. Carbohydrates as fuels
c. Hydrolysis

B. Lipids

1. Ratio of hydrogen to oxygen as compared to the carbohydrates

2. Parts of a true fat molecule

   a. An alcohol, usually glycerol or glycerine (a tri-alcohol)
   b. A group of compounds known as fatty acids
   c. Ester linkage between glycerol and fatty acids

3. Dehydration synthesis of fatty acids to lipids - relate to carbohydrates and proteins

4. Hydrolysis - relate to carbohydrates and proteins

   a. Lipase - breaking the ester linkage between glycerol and fatty acid molecules
   b. Bile - emulsification

5. Saturated and unsaturated fatty acids and lipids

C. Proteins

1. Amino acids and the primary structure of proteins

   a. Peptide linkage
   b. Dehydration synthesis - relate to fats and carbohydrates

2. Other factors determining the shape of protein molecules

   a. Hydrogen bonding
   b. The alpha helix
   c. Denaturing - permanently breaking the hydrogen bonds
   d. Beta configuration

3. The buffering action of proteins and amino acids

D. Enzymes

1. Characteristics

2. Specificity

3. Theories of enzyme activity

   a. Enzyme - substrate
   b. Lock and key

4. Enzymes and energy

5. Conditions necessary for enzyme activity

COURSE OUTLINE (Continued)

E. Nucleic Acids

1. Types of nucleic acids
2. Chemical composition
3. DNA structure
4. RNA structure
5. Nucleic acids and protein synthesis

III. Blood Chemistry (optional) - See Laboratory Experiments

SPECIAL LABORATORY PROCEDURES

Hutton, W. General Chemistry Laboratory Text with Qualitative Analysis. Instructor's Manual. Columbus, Ohio: Charles E. Merrill, 1968.

1. Potentiometric Acid-Base Titrations (p. 173)
2. Appendix 7: Instructions for Construction of a Simple Poggendorf Potentiometer (p. 311)
3. Iodimetry: Some of the Chief Reasons for the Wide Use of Iodine in Volumetric Analysis Are Summarized (p. 130)
4. Methods of Separating the Components of Heterogeneous and Homogeneous Mixtures (p. 207)
5. Appendix 5: Spectrometer and Photoelectric Colorimeter (p. 301)

LABORATORY EXPERIMENTS

Brescia, Arents, Meislich, Turk. Fundamentals of Chemistry - Laboratory Studies. New York: Academic Press, 1968.

1. Determination of the Normality of a Solution of Sodium Hydroxide From a Known Weight of Potassium Hydrogen Phthalate (p. 105)
2. Oxidation-Reduction Titration: Analysis of an Oxalate (p. 109)
3. Iodimetry: Volumetric Determination of Cu(II) ion by Reaction with Iodide Ion (p. 115)
4. Iodimetry: Determination of Antimony (p. 123)
5. Ion Exchange: Determination of the Concentration of an Anion (Using an Anionic Resin) (p. 129)

LABORATORY EXPERIMENTS (Continued)

6. Colorimetry: Determination of Manganese (See Appendix 5, p. 301)
   To be done only:
   a. If a simple optical colorimeter is available
   b. If a photoelectric spectrometer is available
   An excellent explanation of the Lambert-Beer Law is given. (p. 135)
7. Titration of a Triprotic Acid - H_3PO_4 (p. 141)
8. Oxidation - Reduction Titration Using H_2O_2 and Fe(II) Solutions (p. 145)
9. Oxidation - Reduction Titration Using Chlorax (p. 149)
10. Preparation and Structure of Coordination Complexes (p. 163)
11. Preparation of Polymers - Phenol and Formaldehyde (p. 179)
12. Determination of the Rate Law for a Reaction: Catalysis (p. 201)
13. Effect of Concentration, Surface Area, and Catalyst on the Rate of Reaction - HCl and Mg ribbon (p. 207)
14. Chemical Equilibrium: Effects of Changing Composition (p. 213)
15. pH: Indicators and Hydrolysis (p. 235)
16. Qualitative Analysis: Semimicro Methods. Centrifuge necessary (p. 251)

Hutton, W. General Chemistry Laboratory Text With Qualitative Analysis. Instructor's Manual. Columbus, Ohio: Charles H. Merrill, 1968.

(Many of these experiments are similar to those listed in the Brescia, et al. Laboratory Manual. But there is a great difference between them. These are much more sophisticated and, in some cases, require considerable mathematics background and ability to construct laboratory apparatus.)

17. The Determination of the Composition of Sodium Bicarbonate by Gas Evolution Analysis. Use of the Ideal Gas Law (p. 57)
18. Kinetics of the Reaction between Hydrogen Peroxide and Iodide Ion. Determination of Rate Law (p. 107)
19. The Standardization of a Sodium Thiosulfate Solution (p. 129)
20. Acid-Base Indicators. A Study of the Dissociation of a Weak Acid (p. 157)
21. The Preparation of Standard NaOH and HCl Solutions (p. 167)
22. The Neutralization of a Polyprotic Acid, H_3PO_4, with a Strong Base.
    Potentiometric acid-base titrations.
    Chemical equilibrium and chemical indicators.
    Titration curves.
    A quinhydrone electrode, platinum reference electrode, and potentiometer are needed. See Appendix 7, p. 311. (p. 173)
23. The Determination of the Total Base Strength of Soda Ash (p. 183)
24. Extraction and Separation of Components of Mixtures (p. 207)
25. Separation of Cations from Aqueous Solution by Column Chromatography (No special equipment needed) (p. 231)
26. The Separation of Cations by Paper Chromatography (p. 235)
27. The Separation of Cations from Aqueous Solution by Ion Exchange Chromatography (p. 241)

LABORATORY EXPERIMENTS (Continued)

Moore, J. A. et al. BSCS Student Laboratory Guide, Yellow Version. New York: Harcourt, Brace and World, 1963.

28. Diffusion Through a Membrance (p. 45)
29. Enzymes in Living Tissues - Catalase (p. 53)
30. Enzyme Action on a Protein (p. 55)
31. Factors Influencing Enzyme Activity (p. 59)
32. Digestion of Foods by Microorganisms (p. 91)
33. Human Kidney Function (Maintaining the homeostatic condition of the blood) (p. 187)
34. Sickle Cells and Selection - Use for differences in hemoglobin structure (p. 255)
    Additional Reference: Sickle Cells and Evolution. A. C. Allison Scientific American, August, 1956.
35. Malaria Life Cycle (p. 3)
    Prepared slides or blood samples from Jackson Memorial.
    Relate malaria to sickle cell anemia. Immunological studies.
    Same additional reference as Experiment 34.

Berman, William. Experimental Biology. New York: Sentinel Books, 1963.

36. Hemoglobin Turns Bright Red in the Presence of Oxygen (p. 61)
    Use dialysis technique
    Dried blood (fertilizer) in a chloroplast suspension
37. Extracting Enzymes from Microscopic Cells. Fermentation with Yeast Extract. "Zymase" is tested on a group of sugar substrates; sucrose, glucose, maltose, lactose, etc. (p. 103)
38. Discovering the Function of Catalase (p. 111)
39. Paper Chromatography

Morholt, Brandwein, Joseph. A Sourcebook for the Biological Sciences, 2nd ed. New York: Harcourt, Brace and World, 1966.

40. Preparation of the Reagents and Solutions Needed, e.g. Benedict's, Lugol's Biuret, Buffer Solutions, Normal Saline, Stains and Indicators. (p. 658)
41. Evolution of Photosynthesizing Systems (p. 159)
42. Cell Contents, Macromolecules
    Separation of molecules by dialysis
    Pentose sugars in plants
    Xylose compared with glucose (p. 134)

LABORATORY EXPERIMENTS (Continued)

43. Tests for Proteins
Millon's Test for sulfhydryl groups - Tyrosine, Tryptophan, Cysteine
Nitroprusside Test for sulfhydryl group
Tryptophan reaction (p. 135)

44. Test for Proteins
Biuret Test for 2 carbamyl ($-CONH_2$) groups. Biuret is specific for the presence of peptide linkage
Ninhydrin Test for the concentration of amino acid (p. 137)

45. Simple Method for Paper Electrophoresis
pH, acidity and alkalinity relative to the isoelectric point of proteins (p. 141)

46. Enzymes
Relate to role of hydrogen acceptors. Removal of hydrogen in oxidation and its transfer to a hydrogen acceptor. Catalase, Dehydrogenase, Cytochrome Oxidase, Phosphorylase (Demonstration), Cholinesterase, Acetylcholine, Amylase, Invertase, Luciferin, Luciferase. (p. 143)

47. Nucleic Acids
Preparation of extract from yeast cells (DNA and RNA). The hydrolyzed extract contains nucleotides, even hydrolyzed nucleotides. Adenine, cytosine, uracil and guanine are obtained from hydrolyzed RNA. Paper chromatography is used for the separation and identification. (p. 145)

48. Proteolytic Enzymes: Bromelin, Papain (p. 147)

49. Biochemistry of Digestion
Review oxidation of glucose
Respiration quotients of glucose, fatty acids, others
The metabolism of sugars, fats and nitrogenous compounds are all linked in the Krebs Cycle (p. 262)

50. Digestion of Starch by Saliva
Effect of temperature and dilution on enzyme activity (p. 210)

51. Specific Tests for Proteins
Zanthoproteic Test - albumin
Buiret Test - Proteoses and Peptones
Millon's Reaction - Solid Proteins (p. 213)

52. Digestion of Proteins by Pepsin -
Effect of temperature on pepsin digestion
Action of rennin on milk
Digestion by trypsin in the small intestine. Demonstrate optimum pH for trypsin.
Pancreatin and casein of milk; amylase activity of pancreatic juice
Invertase - sucrose hydrolyzed to glucose and fructose (p. 213)

53. Fats: Emulsification
Hydrolysis by lipase (control of pH for neutrality) Small intestine and pancreatic lipase.
Litmus milk test using pancreatin. Show that pancreatin contains digestive enzymes which split fats into fatty acids and proteins into amino acids. (p. 215)

LABORATORY EXPERIMENTS (Continued)

54. Summary of Nutrient Tests: starch, carbohydrates, sugars, proteins, fats and oils, water, minerals. (p. 218)
55. Preparation of Blood Plasma (p. 253)
56. Preparation of Oxalated Blood (p. 251)
57. Preparation of Citrated Blood (p. 660)

If whole blood can be obtained, any Standard Laboratory Procedures Book used by hospitals gives the tests and the reagents needed for human blood chemistry: sugar, urea, non-protein nitrogen, uric acid, albumin-globulin ratio, creatinine, cholesterol, chlorides, calcium, phosphorus, etc.

FILMS

Dade County 16 mm Films

1. Acids, Bases and Salts
   AV# 1-10947, 21', C
2. Acid-Base Indicators
   AV# 1-10788, 19', C
3. Alcohol and the Human Body
   AV# 1-12393, 14', B/W
4. The Atom and Biological Science
   AV# 1-03550, 12' B/W
5. Biochemical Genetics
   AV# 1-30572, 28', C, B/W
6. Chemical Bonding
   AV# 1-10814, 20', C
7. Cell Biology - Growth and Replacement
   AV# 1-30510, 30', C
8. Cell Biology - Transfer of Materials
   AV# 1-30526, 30', C
9. Cell's Chemical Organization
   AV# 1-30505, 30', C, B/W

FILMS (Continued)

10. Digestion, Chemical
AV# 1-11235, 18', B/W

11. Endocrine Glands
AV# 1-03441, 11', B/W

12. Equilibrium
AV# 1-10829, 22', C

13. Foods and Nutrition
AV# 1-03128, 11', B/W

14. Human Body, Nutrition and Metabolism
AV# 1-11244, 14', C

15. Hormones
AV# 1-30479, 28', C. B/W

16. Human Body, Circulatory System
AV# 1-11226, 14', C

17. Patterns of Energy Transfer
AV# 1-30527, 30', C, B/W

18. Water and Life
AV# 1-11054, 15', C

19. Ionic Equilibrium
AV# 1-10930, 16', C

20. Molecular Spectroscopy (No. 4142)
AV# 1-10869, 22', C

21. Properties of Solutions
AV# 1-30345, 28', B/W

CHEM Study Films (Not in Dade County AV)

22. Biochemistry and Molecular Structure
22', C

23. Shapes and Polarities of Molecules
18', C

FILMS (Continued)

Other Films

24. The Chemical Synthesis of Proteins
Available from: Films for the Humanities and Sciences
505 - 8th Avenue
New York, New York 10018

$300 purchase price. $27.50 rental per showing.

RECOMMENDED READINGS

1. Allinger, Norman and Allinger, Janet. Structure of Organic Molecules. Englewood Cliffs, New Jersey: Prentice-Hall, 1965.

2. Baker, J. and Allen, G. Matter, Energy and Life. Atlanta: Addison-Wesley, 1965.

3. Barker, Robert. Organic Chemistry of Biological Compounds. Englewood Cliffs, New Jersey: Prentice-Hall, 1965.

4. McElroy, W. D. Cell Physiology and Biochemistry, 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, 1964.

5. Morholt, Evelyn, et al. A Sourcebook for the Biological Sciences, 2nd ed. New York: Harcourt, Brace and World, 1966.

6. Morrison, R. T. and Boyd, R. N. Organic Chemistry. Boston: Allyn and Bacon, 1963.

An understandable and very comprehensive text, an excellent reference for nomenclature and all types of organic reactions.

Chapter 17, p. 493 Fats: Occurrence and composition; hydrolysis, saponification; fats as sources of pure acids; reduction to alcohols; unsaturated

Chapter 19, p. 518 Amines: Nomenclature; preparation and physical properties; secondary and tertiary amines; amides

Chapter 20, p. 540 Amines: Reactions

Chapter 22, p. 585 Phenols (ArOH)

Chapter 23, p. 611 Aldehydes and Ketones

RECOMMENDED READINGS (Continued)

Chapter 24, p. 650 Glycols

Chapter 25, p. 676 Dicarboxylic Acids (Oxalic, Succinic, Glutaric, Phthalic)

Chapter 26, p. 700 Keto Acids (Pyruvic)

Chapter 27, p. 714 Hydroxy Acids (Lactic, Malic, Tartaric)

Chapter 29, p. 745 Carbohydrates I (Very comprehensive)

Chapter 30, p. 781 Carbohydrates II (Di and Polysaccharides)

Chapter 32, p. 834 Heterocyclic Compounds (Pyridine, Pyrimidine, Purine)

Chapter 33, p. 858 Amino Acids and Proteins: Peptide chain; polypeptide chain; nucleoproteins and nucleic acids, conjugated proteins (prosthetic group) - hemoglobin; amino acids as dipolar ions

7. Richards, J. H., et al. Elements of Organic Chemistry. Atlanta: McGraw-Hill, 1967.

A good text although not as detailed or as comprehensive as Morrison and Boyd except in the area of biological processes.

Chapter 23, p. 375 Biological Processes: Hydrolysis of proteins; enzymes involved in protein hydrolysis; hydration and dehydration and enzymes involved; Krebs Cycle; oxidation and reduction; nicotinamide adenine dinucleotide; lactic dehydrogenase; fermentation; aldolase; biosynthesis of terpenes (steroids); biosynthesis of the biological isoprene unit; polymerization of isopentenyl pyrophosphate; bile acids and steroid hormones

8. Vander Werf, C. A. Acids, Bases and the Chemistry of the Covalent Bond. New York: Reinhold, 1961.

Bronsted-Lowry and Lewis Acid-Base Theories
Important background material, not difficult to read

RECOMMENDED READINGS (Continued)

9. Morrison, J. H. Functional Organelles. New York: Reinhold, 1966.

   p. 46 Glycolysis, Alcoholic Fermentation, Aerobic Respiration in Cells

   p. 47 Synthesis of ATP

   p. 49 Synthesis of ATP

   p. 51 Krebs Cycle

   p. 66 Respiratory Chain: Enzymes are Conjugated Proteins (Prosthetic Group); Krebs Cycle Substrates

   p. 78 Events involved in the ordering of the amino acid sequence of protein by nuclear DNA

   p. 93 Components of the nucleotide subunit of DNA

10. Locke, D. M. Enzymes - The Agents of Life. New York: Crown, 1969.

    Easy reading; up to date; non-technical; good glossary.

11. Vroman, L. Blood. New York: Natural History Press, 1968.

    Written for laymen. Based upon up to date biochemical research.

12. Steiner, R. F. Chemical Foundations of Molecular Biology. Princeton, New Jersey: Van Nostrand, 1965.

    Technical. Excellent structural formulas. Excellent teacher reference.

    Chapter 2 The Amino Acids - Optical activity; neutral, acidic, basic analogs

    Chapter 3 The Chemical Structure of Proteins - Amino acid linkage; Sequential arrangement; Primary structures and variations.

    Chapter 4 The Size, Shape and Electric Charge of Protein Molecules

    Chapter 5 Spatial Organization of Proteins

    Chapter 6 Structure and Function of Certain Important Proteins Collagen, Antibodies, Fibrinogen, Plasma Proteins, Serum Albumin, Hemoglobin, Myoglobin

Chapter 7 Catalytic Proteins: The Enzymes

Chapter 8 The Nucleotides

Chapter 9 Deoxyribonucleic Acids

Chapter 10 Ribonucleic Acids and the Biosynthesis of Proteins

Chapter 11 Nucleic Acids of Viruses as Carriers of Biological Information

Chapter 12 The Carbohydrates and their Biosynthesis

Chapter 13 Energy Transformations by Biological Systems

Appendix C Synthesis of Polypeptides

Appendix D Biological Oxidation and Reduction

13. Balwin, E. Dynamic Aspects of Biochemistry. New York: Cambridge University Press, 1965.

14. Bennet, T. P. and Frieden, E. Modern Topics in Biochemistry: Structure and Function of Biological Molecules. New York: Macmillan, 1967.

Up to date. Technical but not difficult. Excellent on:

Chapter 7 Structure and Function of Carbohydrates

Chapter 11 Macromolecular Biosynthesis

15. Rich, A. and Davidson, N., Editors. Structural Chemistry and Molecular Biology. San Francisco: Freeman, 1968.

A volume dedicated to Linus Pauling by his students, colleagues and friends. Very technical and specialized.

p. 29 "Binding Site of Phosphate Ion to Ribonuclease Molecules" G. Knuth, J. Bello, D. Harker

p. 38 "Structure of an Enzyme" - W. N. Lipscomb

p. 88 "Thought on the Conformation of Proteins in Solution" J. T. Edsall

RECOMMENDED READINGS (Continued)

p. 166 "Antibody Formation: From Ehrlich to Pauling and Return" D. H. Campbell

p. 223 "On the Assembly of Amino Acids into Proteins" - A. Rich

p. 285 "Homocystinuria: A Challenging Molecular Disease" T. L. Perry

p. 399 "Nucleic Acid Replication and Transcription" - H. Jehle, W. C. Parke

p. 423 "The Structure of RNA" - D. R. Davies, G. Filsenfeld

p. 484 "Some Comments on Hydrogen Bonding in Purine and Pyrimidine Bases" - R. E. Marsh

p. 573 "Some Aspects of Heme Stereochemistry" - J. L. Hoard

PERIODICALS

1. "Dilute Solutions of Strong Acids: The Effect of Water on pH." Mogul and Schmuckler. Chemistry, May, 1969.

2. "Effects of Smoking, The." E. Cuyler Hammond. Scientific American, July, 1962.

3. "Enzymes - How They Operate." I. Raw. Chemistry, June, 1967.

4. "Enzyme Molecule in Three Dimensions - Cytochrome c." Chemistry, December, 1969. p. 22.

5. "Evolution of Proteins (Cytochrome c), The." H. Grunewald. Chemistry, January, 1968.

6. "First Synthesis of an Enzyme, Ribonuclease." J. Zimmerman. Chemistry, April, 1969.

7. "Genetics of Schizophrenic and Schizoid Disease, The." L. L. Heston. Science, January 10, 1970.

8. "Hallucinogenic Drugs, The." Barron, Jarvik, Bunnell, Jr. Scientific American, April, 1964.

9. "Lactic Acid." D. S. Sabine. Chemistry, March, 1967.

PERIODICALS (Continued)

10. "Measuring the Weight of Giant Molecules." F. W. Billmeyer, Jr. Chemistry, March, 1966.

11. "Physiology of High Altitude, The." R. J. Hock. Scientific American, February, 1970

12. "Polymerization (Lab Bench)." M. H. Verbrugge. Chemistry, October, 1967.

13. "Schizophrenia - The Body's Chemical Mistake." Chemistry, May, 1970.

14. "Sickle Cells and Evolution." A. C. Allison. Scientific American, August, 1956.

15. "Thin Layer Chromatography (Lab Bench)." J. R. Mueller and B. M. Davis. Chemistry, November, 1966.

16. "Two Decades of Research on the Biosynthesis of Saccharides." L. F. Leloir. Science, June 25, 1971.

17. "Phospholipid-Calcium Phosphate Complex: Enhanced Calcium Migration in the Presence of Phosphate." Science, June 25, 1971, p. 1339.

18. "Regulation of Enzyme Activity." Hames and Wu. Science, June 18, 1971.

19. "Covalent Enzyme Substrate Intermediates." Bell and Koshland, Jr. Science, June 18, 1971.

20. "Stress Collisions and Constants - Part 2 - Buffers." Chemistry, May, 1971.

21. "Spectrophotometric Determinations of pK_a's for Substituted 2-Nitrophenols (Lab Bench)." Chemistry, May, 1971.

22. "Endemic Goiter - Thyroid Hormone." (Good Structural Formulas) H. B. Gillie. Scientific American, June, 1971.

23. "Enzymes Bound to Artificial Matrixes." K. Mosbach. Scientific American, March, 1971.

24. Progress in Treating Sickle Cell Anemia." Chemistry, April, 1971, p. 21.

25. "Energy Transduction in Mitochondria." D. E. Green. The Science Teacher, May, 1971.

PERIODICALS (Continued)

26. "Erythrocyte Metabolism: Interaction with Oxygen Transport." Brewer and Eaton. Science, March 26, 1971.

27. "White House Conference on Food, Nutrition and Health." Final Report. U. S. Government Printing Office, 1971. Section 4: Nutrition Teaching in Elementary and High Schools.

BOOKS

1. Asimov, I. Biochemistry. Garden City, New York: Doubleday, 1962.

2. Asimov, I. Chemicals of Life: Enzymes, Vitamins, Hormones. New York: Abelard-Shuman, 1954.

3. Asimov, I. Life and Energy. Garden City, New York: Doubleday, 1962.

4. Biddle, H. D. and Floutz, V. W. Chemistry in Health and Disease. 5th ed. Philadelphia: F. A. Davis Company, 1960.

5. Bogen, H. J. Biology for the Modern Mind. New York: Macmillan, 1968.

6. Borek, E. The Atoms Within Us. New York: Columbia University Press, 1961.

7. Butler, J. N. Solubility and pH Calculations. Atlanta: Addison-Wesley, 1964.

8. Castka, J. Chemistry Problems. New York: Holt, 1962.

9. Chambers, R. W. and Payne, A. S. From Cell to Test Tube: The Science of Biochemistry. New York: Scribners, 1960.

10. Cheldelin, V. H. and Newburgh, R. W. The Chemistry of Some Life Processes. New York: Reinhold, 1964.

11. Downes, H. R. The Chemistry of Living Cells, 2nd ed. New York: Harper, 1962.

12. Dyer, J. R. Applications of Absorption Spectroscopy of Organic Compounds. Englewood Cliffs, New Jersey: Frentice-Hall, 1965.

13. Galston, A. W. The Life of the Green Plant. Englewood Cliffs, New Jersey: Prentice-Hall, 1964.

BOOKS (Continued)

14. Gutsche, C. D. The Chemistry of Carbonyl Compounds. Englewood Cliffs, New Jersey: Prentice-Hall, 1967.

15. Haldane, J. B. S. Enzymes. Cambridge, Mass.: Massachusetts Institute of Technology Press, 1965.

16. Harrison, K. P. A Guide Book to Biochemistry. New York: Cambridge University Press, 1959.

17. Hodgman, C. D. and others. Tables for Identification of Organic Compounds, 2nd ed. Cleveland, Ohio: Chemical Rubber, 1964.

18. Hoffman, K. B. The Chemistry of Life. Englewood Cliffs, New Jersey: Scholastic Book Services, 1964.

19. Ingram, V. M. The Biosynthesis of Macromolecules. Menlo Park, California: W. A. Benjamin, 1965.

20. Maddox, J. Revolution in Biology. New York: Macmillan, 1964.

21. McDowall, R.J.S. Handbook of Physiology, 43rd ed. Philadelphia: Lippincott, 1960.

22. Miall, L. M. and Sharp, D.W.A. A New Dictionary of Chemistry, 4th ed. New York: Wiley, 1968.

23. Moore, R. The Coil of Life. New York: Knopf, 1961.

24. Nash, L. K. Elements of Chemical Thermodynamics. Atlanta: Addison-Wesley, 1962.

25. Pauling, L. C. The Nature of the Chemical Bond, 3rd ed. Ithaca, New York: Cornell University Press, 1960.

26. Pauling, L. C. and Hayward, R. The Architecture of Molecules. San Francisco: Freeman, 1964.

27. Ryschkewitsch, G. E. Chemical Bonding and the Geometry of Molecules. New York: Reinhold, 1963.

28. Stephenson, W. K. Concepts in Biochemistry: A Programmed Text. New York: Wiley, 1967.

29. Stewart, R. The Investigation of Organic Reactions. Englewood Cliffs, New Jersey: Prentice-Hall, 1966.

30. Watson, J. D. Molecular Biology of the Gene. Menlo Park, California: W. A. Benjamin, 1965.

BOOKS (Continued)

31. Weisz, P. Elements of Biology, 2nd ed. Atlanta: McGraw-Hill, 1965.

32. White A. and others. Principles of Biochemistry, 3rd ed. Atlanta: McGraw-Hill, 1964.

33. White, E. H. Chemical Background for the Biological Sciences. Englewood Cliffs, New Jersey: Prentice-Hall, 1964.

MASTER SHEET--BIOCHEMISTRY

Week	Objectives	Laboratory Experiments	Recommended Readings	Periodicals	Films
1	1	1,2,3,4,5,7,8,9,10,11, 12,13,14,15,16,17,18, 19,20,22,23,24	1,2,3,4,6,8	1,21	1,2,4,6,9,12, 19,20,21,22,23
2	2,3,7	6,25,26,27,42	1,2,3,4,5,6,7,9,12, 13,14	9,16,25,27	3,8,10,13,14,16
3	11,12	28,40,49,50,54	1,2,3,4,5,6,7,12,13, 14		17,18
4	2,3,7	49,53,54	1,2,3,4,5,6,7,12,13, 14	17,27	8,10,13,14
5	2,3,4,7	39,43,44,45	1,2,3,4,5,6,7,9,12, 13,14	5,10,12,15, 20,22,27	7,8,10,13,14
6	5,6	48,51,52,53,54	1,2,3,4,5,6,7,9,12, 13,14,15		11,24
7	8,9,10	29,30,31,32,37,38	1,2,3,4,5,6,7,10,12, 13,14,15	3,4,6,18,19, 20,22,23	15
8	10,13	46,47,48,54	1,2,3,4,5,6,7,9,12, 13,14,15		
9	13 Optional	33,34,35,36,55,56, 57	1,2,3,4,5,6,7,9,11, 12,13,14,15	2,6,7,8,11, 13,14,24,26	5