Study Guide Sample Questions

Molecules That Changed the World

K. C. Nicolaou and Tamsyn Montagnon
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Chapter 1: Introduction: Atoms, Molecules & Synthesis

1. Give a brief description (25 words or less) of the following terms:
    a) The Big Bang Theory
    b) The Atomic Theory of Matter
    c) The Periodic Table
    d) Deoxyribo nucleic acid
    e) Ribo nucleic acid
    f) Protein
    g) Secondary metabolite
    h) Chemical synthesis

2. Identify the scientific contributions of the following philosophers–scientists (10 words or less):
    a) Demokritos
    b) Dmitri Ivanovich Mendeleev
    c) John Dalton
    d) Aristotle

3. Give the names and symbols of four elements and four molecular structures essential for life on Earth (including stereochemistry when appropriate):

4. Give the names of 8 natural products and name the three main categories of living systems from which such natural products are isolated.

5. Name the milestone event in 1828 that symbolizes the birth of organic synthesis.

6. The impact of chemical synthesis on modern society has greatly enhanced the lives of people. Give five examples of such contributions:

7. Name three methods used today in the structural elucidation of organic molecules.

Chapter 2: Urea & Acetic Acid

1. Describe the following terms (50 words or less):

   a) Vitalism

   b) Synthetic organic chemistry (or chemical synthesis, or organic synthesis)

2. Draw the structures of urea and acetic acid. In addition, name the chemists who first synthesized them in the laboratory and articulate the significance of each accomplishment. (10 words or less)

3. Name the countries in which the following eminent chemists worked and made their most important contributions in chemistry.

   a) Friedrich Wöhler
   b) Justus von Liebig
   c) Jöns Jakob Berzelius
   d) Antoine Laurent de Lavoisier
   e) Robert Boyle
   f) John Dalton
   g) August Wilhelm von Hofmann
   h) Hermann Kolbe
   i) Friedrich August Kekulé
   j) Joseph Priestley

Chapter 3: Glucose

1. Briefly describe (100 words or less) the photosynthesis of glucose from carbon dioxide in green plants, including the structures of starting materials, key intermediates, and products.

2. Mention two scientific accomplishments of Emil Fischer for which he is well known, the year of his awarding of the Nobel Prize in Chemistry, and the country he represents.

3. Give the molecular structures (with stereochemistry) of lactose and fructose and the names of two naturally occurring carbohydrate-based biopolymers.

4. In a short essay (100 words or less), including the names of Pasteur, Le Bel and van't Hoff, and the terms of plane polarized light, tetrahedral carbon, and enantiomers, explain the phenomenon of enantioisomerism.

5. Briefly describe (100 words or less) the biotransformation of glucose in the presence of yeast to ethanol and carbon dioxide, including the structures of the key intermediates involved, and give two examples of how this phenomenon is exploited in everyday life.

Chapter 4: Aspirin®

1. Name two ancient civilizations in which pain was treated with herbal medicines.

2. Acetylsalicylic acid (Aspirin®) was prepared by chemical synthesis just before the dawn of the 20th century. The synthesis started from phenol and involved two steps. Give the two steps using molecular formulas of starting material, intermediate, and product as well as the reagents and conditions used. Name the chemist responsible for each step.

3. Name the three scientists who won the Nobel Prize in Medicine or Physiology in 1982 for their work on the arachidonic acid metabolites.

4. Describe (10 words or less) the mechanism of action of aspirin and related medicines.

5. Draw the structures of the following naturally occurring molecules:

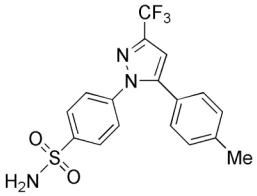
   a) Salicin

   b) Arachidonic acid

   c) Prostacyclin

   d) Thromboxane

6. Match the following names of pain-relieving medications with the appropriate molecular structure of their active ingredient. (Tylenol®, Vioxx®, Advil®, Celebrex®)



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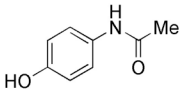

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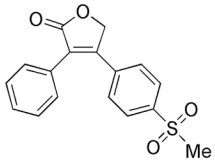

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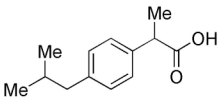

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Chapter 5: Camphor

1. *Cinnamomum camphora*, as species of laurel trees, produces a substance that has been used for centuries for medicinal and embalming purposes as well as scent in various instances. Name that compound, give its molecular structure, and provide the name of the first chemist to synthesize it.

2. Explain (25 words or less) Bredt's rule in organic chemistry and give the starting material of a modern industrial process for the production of the compound isolated from *Cinnamomun camphora*.

Chapter 6: Terpineol

1. Define the term terpene and name four members of this class of natural products.

2. Give the molecular structure of terpineol, its natural source, and name of the chemist who synthesized it in the laboratory for the first time.

3. Provide the names and molecular structures of the naturally occurring compounds responsible for the fragrances of the following items:

   a) Musk

   b) Roses

   c) Sweet vanilla

   d) Geranium

4. Describe with chemical formulas and chemical equations the preparation of a Grignard reagent and its use in chemical synthesis.

Chapter 7: Tropinone

1. Define the term alkaloid and name five members of this family of natural products.

2. Describe with molecular structures, reagents and conditions, and mechanistic arrows where appropriate, the total synthesis of tropinone by Sir Robert Robinson.

3. Name one theory, discovery, or invention associated with each of the following scientists, clearly designating those who won a Nobel Prize in Chemistry.

   a) Sir Robert Robinson (other than the synthesis of tropinone)

   b) Friedrick August Kekulé

   c) Irving Langmuir

   d) Linus Pauling

   e) Carl Wilhelm Scheele

   f) Friedrich Wilhelm Adam Sertürner

Chapter 8: Haemin

1. Provide the molecular structure of haemin and explain its role in biology (25 words or less).

2. Give the molecular structures of Tyrian purple and indigo, and name two additional famous dyes.

3. Briefly describe (50 words or less) how mauveine was discovered and by whom.

4. Describe (25 words or less) one contribution for each of the following three chemists to the field of aromaticity: Friedrich August Kekulé, Erich Hückel, Franz Sondheimer; and name and draw the molecular structures of three aromatic compounds.

Chapter 9: Quinine

1. Briefly describe (100 words or less) how malaria and quinine have influenced our society throughout time.

2. Explain the role of each of the following in the story of malaria and quinine:

   a) *Plasmodium falciparum*

   b) The Incas

   c) The Chincona tree

   d) The Melinda and Bill Gates Foundation

3. Name the contributions of the following chemists to the chemistry of quinine:

   a) Joseph Bienaimé Caventou and Pierre Joseph Pelletier

   b) Paul Rabe

   c) Robert B. Woodward

   d) Gilbert Stork

Chapter 10: Morphine

1. Draw clearly, including stereochemistry, the molecular structures of two of the following molecules: morphine, codeine, heroin, cocaine and caffeine.

2. One of the critical steps in the first total synthesis of (±)-morphine involved a Diels–Alder reaction, whereas a subsequent asymmetric synthesis of (–)-morphine involved a catalytic asymmetric allylic ether formation. Answer the following questions about these historical accomplishments.

   a) Name the main scientist involved in each of these syntheses.

   b) Name and draw the structure of the diene employed in the Diels–Alder reaction of the first synthesis.

   c) Draw and name the catalyst used for the allylic ether formation in the subsequent asymmetric synthesis.

3. The reaction of *para*-quinone and cyclopentadiene gives rise to a 1:1 adduct. Using molecular structures depict this powerful reaction and name its discoverers.

4. Write informative notes on the following people or items (10 words or less).

   a) Pedanius Dioscorides

   b) Paracelsus (Theophrastus Phillippus Aureolus Bombastus von Hohenheim)

   c) Ebers Papyrus

   d) Opium

   e) Methadone

   f) Cannabis plant

   g) Opioid receptor

   h) Morpheus

   i) Laudanum

   j) Kenichi Fukui

Chapter 11: Steroids & the Pill

1. Give the molecular structures, including stereochemistry, of cholesterol and estrone.

2. Briefly describe the contribution of the following important key players in the chemistry of steroids (10 words or less):

   a) Werner E. Bachmann

   b) Robert B. Woodward

   c) William S. Johnson

   d) K. Peter C. Vollhardt

   e) Adolf O. R. Windhaus

   f) Carl Djerassi

g) Russell E. Marker

h) Margaret Sanger

i) Gregory Pincus

4. R. B. Woodward, Sir Derek Barton, and George Olah each won a Nobel Prize for their important discoveries in chemistry. Briefly describe their contributions (50 words or less, for each).

Chapter 12: Strychnine

1. For what is the molecule of strychnine most famous (or infamous)?

2. What is the association of each of the following names with strychnine:

   a) *Strychnos ignatii*

   b) Joseph Bienaimé Caventou and Pierre Joseph Pelletier

   c) Sir Robert Robinson

   d) R. B. Woodward

3. Provide the structures, including stereochemistry, of coniine, nicotine and cocaine.

Chapter 13: Penicillin

1. Provide the structure, including stereochemistry, of penicillin V and give the name of its discoverer.

2. Write a short essay (100 words or less) on the impact of the discovery of penicillin on medicine and society.

3. What is the association of each of the following persons with penicillin?

    a) Dorothy Crowfoot Hodgkin

    b) General Dwight D. Eisenhower

    c) John Sheehan

    d) Sir Jack Baldwin

4. Name the three recipients of the 1945 Nobel Prize in Physiology or Medicine for the penicillin success story.

5. Provide the name and structure of the reagent developed and employed for the construction of the ß-lactam ring of penicillin in the first total synthesis of this antibiotic.

Chapter 14: Longifolene

1. Briefly describe (100 words or less) what is meant by the term ‘Retrosynthetic Analysis’ in the context of the art of total synthesis, mentioning the famous chemist who developed it, the first molecule to which it was applied, and how this theory has impacted education and research.

Chapter 15: Prostaglandins and Leukotrienes

1. Provide the structures (with stereochemistry) of four of the following molecules:

   a) Prostaglandin $F_{2\alpha}$

   b) Arachidonic acid

   c) Prostaglandin H_2

   d) Thromboxane A_2

   e) Prostacyclin

   f) Leukotriene D_4

2. Describe (50 words or less) the contributions of E. J. Corey to the field of prostaglandins and leukotrienes, and explain how these contributions have impacted biology and medicine.

3. Name the three recipients of the 1982 Nobel Prize in Physiology or Medicine for discoveries in the prostaglandin and related areas, and mention one specific contribution of each scientist.

4. Mention one biological source, one physiological role, and one medical application derived from research within the prostaglandin field.

5. Mention one biological source, one physiological role, and one medical application derived from research related to the leukotriene field.

Chapter 16: Vitamin B_{12}

1. Briefly describe (50 words or less) the contribution of James Lind to the discovery of vitamins.

2. Write the structures (including stereochemistry) of vitamins C, vitamin E (α-tocopherol), and vitamin B_6, and state the beneficial function of each to the human body.

3. Name the contribution to the field of vitamin B_{12} of each of the following scientists.

   a) Dorothy Crowfoot Hodgkin

   b) R. B. Woodward

   c) Albert Eschenmoser

   d) Sir Alan R. Battersby

   e) A. Ian Scott

4. Describe briefly (50 words or less) the term ‘Woodward–Hoffmann Rules’.

Chapter 17: Erythronolide B and Erythromycin A

1. Explain the clinical applications of the erythromycins.

2. Name one discovery or accomplishment within the field of antibiotics for each of the following scientists.

   a) Selman A. Waksman

   b) E. J. Corey

   c) R. B. Woodward

3. Describe briefly the double activation macrolactonization method and use chemical drawings to illustrate this process.

Chapter 18: Monensin

1. Describe briefly (50 words or less) the mechanism of action of monensin and its uses today.

2. Write the structure of 18-Crown-6, mention its main chemical properties, and name the three scientists that shared the 1987 Nobel Prize in Chemistry for their studies on this and related molecules.

3. Name the synthetic organic chemist responsible for the first total synthesis of monensin.

4. Describe briefly (50 words or less) the hydroboration reaction, mentioning the chemist most closely associated with its development and its applications to chemical synthesis.

Chapter 19: Avermectin

1. Name the discoverer of avermectin $B_{1\alpha}$ and briefly describe its biological properties.

2. Outline briefly (25 words or less) the industrial production of ivermectin, and name two important uses of this molecule.

3. What is the connection of the following scientists and institutes with avermectin $B_{1\alpha}$ and ivermectin:

   a) Samuel J. Danishefsky

   b) Stephen Hanessian

   c) P. Roy Vagelos

   d) Merck Pharmaceutical Company

   e) The Kitasato Institute

4. Define the term protecting group (PG) in chemical synthesis, and give an example.

Chapter 20: Amphotericin B

1. Write notes (50 words or less) on amphotericin B, stating its main structural motifs, biological properties, and medical applications.

2. Name three species of fungi and explain how each one plays a beneficial role in everyday life.

3. Name three scientists whose work advanced the chemistry of amphotericin B.

4. Describe briefly the Wittig reaction using formulas, and mention its significance for organic synthesis.

Chapter 21: Ginkgolide B

1. Write a short essay (100 words or less) on the history of the ginkgo tree and the uses of the *Ginkgo biloba* extracts.

2. Give the names and contributions of two chemists whose work advanced the chemistry of ginkgolide B.

Chapter 22: Cyclosporin, FK506 & Rapamycin

1. Describe (50 words or less) the impact of cyclosporine, FK506 and rapamycin on medicine and society.

2. Give the contribution of each of the following individuals to the chemistry, biology, or medicine of cyclosporine, FK506, or rapamycin, and name the company at which each of these molecules was discovered and developed as a drug.

   a) Jean-François Borel and Hertmann F. Stähelin

   b) Stuart Schreiber

   c) Thomas Earl Starzl

3. In a short paragraph (50 words or less) outline the impact of palladium catalysis on modern chemical synthesis and mention four chemists whose work has decisively advanced this field.

Chapter 23: Calicheamicin γ_1^I

1. Write a short essay (100 words or less) on the story of calichaemicin γ_1^I describing its discovery, mechanism of action, and development into a drug.

2. Name three scientists and their contributions to the chemistry, biology, or medicine of calichaemicin γ_1^I.

3. Illustrate with structures the cycloaromatization reaction involved in the mode of action of calichaemicin γ_1^I and name the inventor of this reaction.

Chapter 24: Palytoxin

1. Name the marine creature from which palytoxin was isolated, its biological activity, and three scientists who were involved in its structural elucidation.

2. Name the chemist responsible for the total synthesis of palytoxin, the significance of this accomplishment, and the named organic reaction developed during the synthesis.

3. Name the toxins associated with the following species.

   a) Fuku fish

   b) Alaska butter clams

   c) Colombian poison arrow frog

Chapter 25: Taxol®

1. Write a brief history (250 words or less) of the discovery, synthesis and development of Taxol® as an anticancer drug. Provide names of the key players beginning with Julius Caesar.

2. Draw the molecular structures of Taxol® and Taxotere®, including stereochemistry, and name their natural sources.

3. Briefly describe the mechanism of action of Taxol® as an anticancer drug (25 words or less), indicating why it is not free of side effects. Suggest, in general terms, how you could improve its properties as a medicine.

4. Name four anticancer drugs other than Taxol® and indicate their chemical nature (e.g. natural product, synthetic compound, antibody, peptide, etc).

Chapter 26: Mevacor, Zaragozic Acids and the CP Molecules

1. Name two naturally occurring fatty acids (and their source) that are beneficial to human health.

2. Name two drugs used to treat cardiovascular disease and explain how they work.

3. The regulation of cholesterol biosynthesis in the human body through medical intervention led to a marked improvement of human health. Using the following keywords write an essay (100 words or less) explaining in scientific terms how this came about (HMG CoA, mevalonic acid, cholesterol, HMG CoA reductase, Mevacor®, Lipitor®).

4. In a short paragraph (50 words or less) describe the scientific contribution of Michael S. Brown and Joseph L. Goldstein and its implication to medicine for which they received the Nobel Prize in Physiology or Medicine.

5. Name three natural products possessing cholesterol-lowering properties and for each name one scientist whose group synthesized the molecule in the laboratory.

6. Using chemical structures, describe the asymmetric epoxidation of allylic alcohols and the asymmetric dihydroxylation of olefins, and name the chemist recognized with the Nobel Prize in Chemistry for the development of these reactions.

Chapter 27: Brevetoxin B

1. Write a short essay (100 words or less) on brevetoxin B, mentioning its occurrence in nature, its biological properties, and its impact on the environment and human health.

2. Name the scientists who elucidated the structure of brevetoxin B in 1981 and the group that synthesized it in 1995.

3. Write informative notes (10 words or less for each) on the following:

   a) Ciguatoxin

   b) Maitotoxin

   c) Azaspiracid-1

   d) *Gambieriscus toxicus*

   e) *Karenia brevis*

4. The following marine organisms produce toxins that cause health hazards to marine life and humans. Match the toxin with its producing organism from the lists below.

List 1: Toxins		List 2: Marine organisms
i) Maitotoxin	_____	a) Puffer fish (fugu)
ii) Azaspiracid-1	_____	b) *Karenia brevis*
iii) Brevetoxin A	_____	c) *Gambierdiscus toxicus*
iv) Brevetoxin B	_____	d) *Mytilus edulis* mussels
v) Tetrodotoxin	_____	e) *Gymnothorax javanicus*
vi) Ciguatoxin	_____	

5. Name two marine toxins most often associated with the “red tide” phenomena and two marine toxins associated with the ciguatera poisoning phenomena, and explain their mechanism of action.

6. Name two scientists associated with the isolation and structural elucidation of marine toxins and identify a molecule each has isolated.

7. Name two chemists associated with the total synthesis of marine toxins and identify which molecule each has synthesized.

8. Write an informative paragraph on azaspiracid-1, the causative agent of the azaspiracid poisoning (AZP) (25 words or less).

Chapter 28: Ecteinascidin 743

1. Sea squirts (or ascidians) produce a substance that possesses an interesting molecular architecture and important biological properties that led to its recent approval as an anticancer drug. Name that compound, the scientist who discovered it, the synthetic organic chemist credited with its first total synthesis, and its mechanism of action.

2. Name three marine natural products, three chemists associated with the discovery of marine natural products, and three synthetic organic chemists associated with the total synthesis of marine natural products.

3. Identify three chemists responsible for the development of the hydrogenation reaction and briefly explain their contribution.

Chapter 29: Epothilones

1. Write a short essay (100 words or less) on the epothilones mentioning their isolation, molecular structure, biological properties, mechanism of action, and medical implications.

2. Name three research groups whose names are associated with the total synthesis of epothilones and three pharmaceutical companies involved in their development or distribution as pharmaceutical drugs.

3. Name the contributions of the following scientists for which they won the Nobel Prize in Chemistry:

   a) Bruce Merrifield

   b) Yves Chauvin, Robert H. Grubbs and Richard R. Schrock (collectively)

Chapter 30: Resiniferatoxin

1. Write a short historical essay on spices and the spice trade (100 words or less).

2. Name the five taste categories and give one molecule associated with each.

3. Provide the molecular structure and the food or spice item associated with each of the following molecules:

    a) Capsaisin

    b) Vanillin

    c) Piperine

    d) Cinnamaldehyde

    e) Sucrose

    f) Caffeine

4. Name the two scientists who won the 2004 Nobel Prize in Physiology or Medicine for their studies on the molecules and processes involved in olfaction (smell) and name the synthetic organic chemist credited with the total synthesis of resiniferatoxin.

Chapter 31: Vancomycin

1. Provide a scientific explanation (50 words or less) of how bacteria develop drug resistance and name two drug resistant bacterial strains.

2. Describe briefly (50 words or less) the mechanism of action of vancomycin.

3. Give the names of the three research groups responsible for the chemical synthesis of vancomycin, or vancomycin aglycon.

4. Depict the aldol reaction with formulas and name three synthetic organic chemists whose work contributed to its development as a powerful synthetic tool.

Chapter 32: Thiostrepton

1. Name three molecules used in veterinary medicine today.

2. Mention three mechanisms by which antibiotics exert their action against bacteria and point out the one operating in the case of thiostrepton.

3. Name the scientists who are associated with the following accomplishments.

   a) The X-ray crystallographic analysis of the yeast RNA polymerase II transcribing complex

   b) The total synthesis of thiostrepton

   c) The biosynthesis of thiostrepton

Chapter 33: Small Molecule Drugs

1. Modern drug discovery and development is a challenging process that can only take place when the different branches of science join forces. Outline the critical roles of the following groups of players (50 words or less, for each).

    a) Biologists

    b) Chemists

    c) Physicians

2. Give an example (name, clinical indication, and molecular structure) for each of the following classes of small molecule drugs.

    a) Barbiturates

    b) Diazepines

    c) Selective serotonin reuptake inhibitors (SSRIs)

    d) Amphetamines

3. Name and draw the molecular structures of four antiviral drugs.

4. Briefly name the contribution for which each of the following groups of scientists received a Nobel Prize (10 words or less).

    a) James Watson and Francis Crick (Nobel Prize in Physiology or Medicine, 1962)

    b) Sir James W. Black, Gertrude B. Elion, and George H. Hitchings (Nobel Prize in Physiology or Medicine, 1988)

    c) Robert F. Furchgott, Louis J. Ignarro, and Ferid Murad (Nobel Prize in Physiology or Medicine, 1998)

    d) J. Robin Warren and Barry J. Marshall (Nobel Prize in Physiology or Medicine, 2005)

5. Write an informative paragraph (100 words or less) about Alfred Nobel and name the six subjects that are recognized by the Nobel Prize every year.

6. Draw the molecular structure for each of the following drugs and indicate for which medical condition they are used.

   a) Nexium®

   b) Prozac®

   c) Tamiflu®

   d) Retrovir® (AZT)

   e) Viagra®

Chapter 34: Biologics

1. Briefly define (10 words or less) the terms 'Small Molecule Drug' and 'Biological Drug' and assign the following drugs to their proper category:
   Herceptin®, Enbrel®, Epogen, Insulin, Measles vaccine, Tagamet®, Valium®, Invirase®, Propranolol, Crixivan®, Luminal® (phenobarbital)

   I. Small Molecule Drug

   II. Biological Drug

2. Describe the contributions of five of the following scientists (10 words or less for each), whose work collectively provided the foundation for the birth of biotechnology and for which some of them were awarded a Nobel Prize.

   a) James Watson and Francis Crick

   b) Paul Berg

   c) H. Gobind Khorana

   d) Frederick Sanger

   e) Walter Gilbert

   f) Kary Mullis

   g) Stanley Cohen

h) Edward Jenner

i) Dennis Slamon

j) Marvin H. Caruthers

3. Name two major biotechnology companies in the United States and mention two biological drug products for each.

   I.

   II.