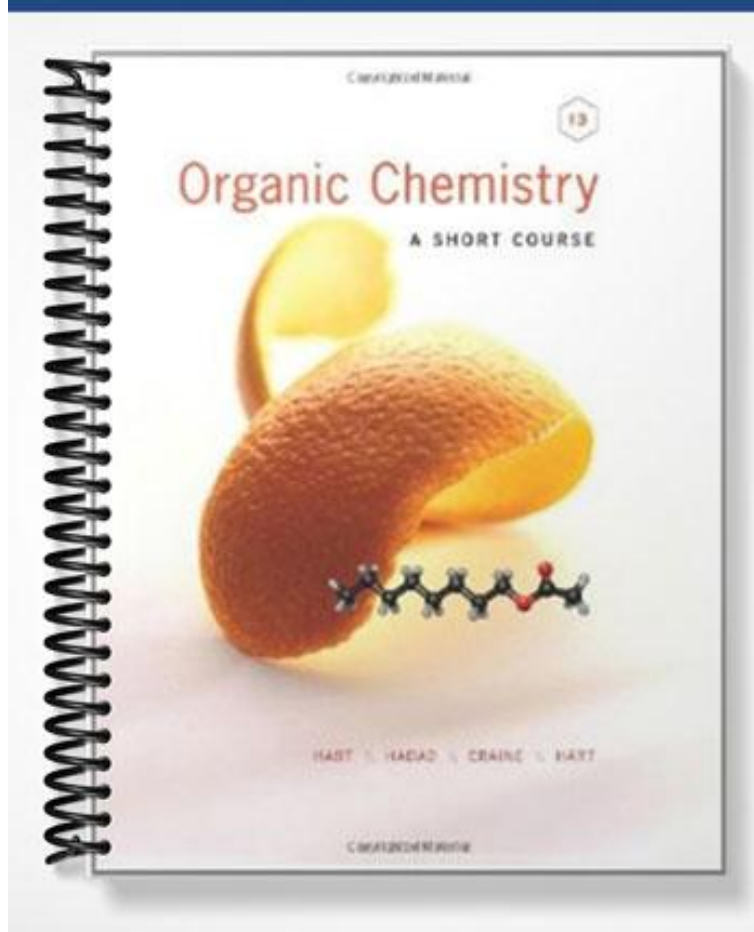


SOLUTIONS MANUAL



Part I

The Text

Summary

Table 1 lists the number of sections per chapter and suggests an approximate number of lectures for each chapter. There is no reason why one chapter cannot be completed and another begun in a given lecture.

The first 11 chapters cover the chemistry of the most important functional groups as well as the principles of stereochemistry and reaction mechanisms. These chapters form the core of organic chemistry; indeed, students who master the material in these chapters will have a sound knowledge of the subject's fundamentals. Any short course in organic chemistry should include most of what is contained in these 11 chapters.

The remaining 7 chapters are special topics and need not be covered in their entirety nor necessarily in the order presented. Chapters 12 to 14, on spectroscopy, heterocyclics, and polymers, are directly related to conventional organic chemistry, whereas Chapters 15 to 18 deal with major classes of biologically important molecules: lipids, carbohydrates, proteins, and nucleic acids. The extent to which the material in these chapters can or will be covered in a short organic course depends on several factors, including the time available and the special interest of the students and the instructor. Not all of this material can be covered thoroughly in a conventional 15-week, 3-lecture-a-week semester course, so as the instructor you will have to decide for your own particular class. Fortunately, the sections in each chapter are numbered, so you can include only selected parts of each chapter if you so wish—simply let the students know which sections to study and which to omit.

The textbook also contains additional materials that can be used at the discretion of the instructor. There are 37 “A Word About” sections (see Table 2) that present brief essays on applications of organic chemistry to industry, biology, and everyday life. There are 11 “A Closer Look At” sections (see Table 3) that provide Web activities that can serve as springboards for class discussions or projects. Finally, the book is accompanied by a CD with 26 visualizations and structures (see Table 4) that can help students visualize organic structures and reaction mechanisms. All of these additional materials are clearly coded in the text with special icons.

Problems

The true test of whether students understand the text material is their ability to solve problems. The text includes a substantial number of problems, as summarized in Table 3. We usually assign many of these problems as homework, but because the answers are available in the study guide, it is not necessary that this homework be turned in and graded. Instead, in the recitation section, you might give a weekly quiz on material taken *directly* from the assigned homework problems (students alerted to this in advance will have a strong incentive to complete the assignments). Alternatively, you could give quizzes on problems similar to, but not identical to the homework problems.

The text also contains many worked examples within each chapter. Perhaps because the solutions are also given, some students tend to skip these examples as they read through a chapter. However, it is still worthwhile to go over some of the examples in class.

Table 1 Number of Sections and Suggested Number of Lectures for Each Chapter

Chapter	Title	Sections*	Suggested No. of Lectures
1	Bonding and Isomerism	18	2–3
2	Alkanes and Cycloalkanes; Conformational and Geometric Isomerism	13	2–3
3	Alkenes and Alkynes	21	4–6
4	Aromatic Compounds	13	2–3
5	Stereoisomerism	12	2–3
6	Organic Halogen Compounds; Substitution and Elimination Reactions	9	2–3
7	Alcohols, Phenols, and Thiols	17	2–3
8	Ethers and Epoxides	9	1–2
9	Aldehydes and Ketones	19	3–4
10	Carboxylic Acids and Their Derivatives	22	3–4
11	Amines and Related Nitrogen Compounds	13	2–3
12	Spectroscopy and Structure Determination	6	2
13	Heterocyclic Compounds	13	2–3
14	Synthetic Polymers	9	1–2
15	Lipids and Detergents	9	1–2
16	Carbohydrates	17	2–3
17	Amino Acids, Peptides, and Proteins	15	2–3
18	Nucleotides and Nucleic Acids	12	1–2
	Total		35–53

* “A Word About” and “A Closer Look” sections are not included; for a separate listing, see Tables 2 and 3.

Table 2 The “A Word About” Sections

Chapter	No.	Page	Title
2	1	60	Isomers, Possible and Impossible
2	2	65	Methane, Marsh Gas, and Miller’s Experiment
3	3	82	The Chemistry of Vision
3	4	104	Ethylene: Raw Material and Plant Hormone
3	5	108	Petroleum, Gasoline, and Octane Number
4	6	140	Polycyclic Aromatic Hydrocarbons and Cancer
4	7	142	C60, an Aromatic Sphere: The Fullerenes
5	8	162	Pasteur’s Experiments and the van’t Hoff-LeBel Explanation
5	9	174	Enantiomers and Biological Activity
6	10	194	S _N 2 Reactions in Nature: Biological Methylations
6	11	200	CFCs, the Ozone Layer, and Trade-Offs
6	12	202	Halogenated Organic Compounds from the Sea
7	13	209	Industrial Alcohols
7	14	223	Biologically Important Alcohols and Phenols
7	15	226	Quinones and the Bombardier Beetle
7	16	229	Hair, Curly or Straight
8	17	243	Ether and Anesthesia
8	18	245	The Gypsy Moth’s Epoxide
9	19	278	Water Treatment and the Chemistry of Enols and Enolates
10	20	297	Green Chemistry and Ibuprofen: A Case Study
10	21	311	Thioesters, Nature’s Acyl-Activating Groups
11	22	339	Alkaloids and the Dart-Poison Frogs
12	23	366	NMR in Biology and Medicine
13	24	400	Porphyrins: What Makes Blood Red and Grass Green?
13	25	403	Morphine and Other Nitrogen-Containing Drugs
14	26	419	Polyacetylene and Conducting Polymers
14	27	424	Degradable Polymers
14	28	425	Aramids, the Latest in Polyamides
15	29	445	Commercial Detergents
15	30	448	Prostaglandins, Aspirin, and Pain
16	31	477	Sweetness and Sweeteners
16	32	480	Fat Substitutes from Carbohydrates
17	33	500	Some Naturally Occurring Peptides
17	34	507	Protein Sequencing and Evolution
18	35	531	DNA and Crime
18	36	539	The Human Genome
18	37	540	Nucleic Acids and Viruses

Table 3 The “A Closer Look At” Sections

Chapter	Page	Number	Title
2	49	1	Natural Gas
2	51	2	Hydrogen Bonding
3	111	3	Petroleum
4	141	4	Polycyclic Aromatic Hydrocarbons
5	176	5	Thalidomide
8	241	6	MTBE (Methyl <i>Tert</i> -Butyl Ether)
10	298	7	Green Chemistry
12	379	8	Mass Spectrometry and Carbon Dating
14	427	9	Nylon
17	517	10	Nobel Laureates and Protein Chemistry
18	536	11	The Polymerase Chain Reaction (PCR)

Table 4 Structures and Visualizations

Chapter	Page	Structure/Visualization	Title
1	20	Structures	models of pentane, isopentane and neopentane
1	31	Structures	model of methane
2	42	Structures	models of ethane, propane and butane
2	53	Visualization	rotation around the C—C of ethane
2	57	Visualization	ring flip in cyclohexane
3	78	Structures	model of ethylene
3	89	Visualization	addition of HCl to ethylene
3	100	Visualization	Diels-Alder reaction
3	106	Structures	model of acetylene
4	122	Structures	model of benzene
4	128	Visualization	electrophilic aromatic substitution
5	151	Visualization	superposition of identical molecules
5	151	Visualization	superposition of enantiomers
6	188	Visualization	S _N 2 Reaction
6	190	Visualization	S _N 1 Reaction
6	196	Visualization	E2 Reaction
6	196	Visualization	E1 Reaction
9	262	Visualization	nucleophilic addition to a carbonyl group
10	301	Visualization	nucleophilic acyl substitution
11	326	Structures	models of trimethylamine
11	330	Structures	models of tetramethylammonium iodide
12	369	Visualization	molecular vibrations
16	468	Structures	α -D-glucopyranose
16	468	Structures	β -D-glucopyranose
17	493	Structures	model of alanine
18	534	Visualizations	DNA structures

Table 5 Number of Worked Examples and Problems in Each Chapter of *Organic Chemistry: A Short Course*

Chapter	Title	Worked Examples	Problems		
			Within	Additional	Total
1	Bonding and Isomerism	15	30	30	60
2	Alkanes and Cycloalkanes; Conformational and Geometric Isomerism	6	25	23	48
3	Alkenes and Alkynes	8	32	29	61
4	Aromatic Compounds	3	19	25	44
5	Stereoisomerism	7	25	31	56
6	Organic Halogen Compounds; Substitution and Elimination Reactions	8	10	17	27
7	Alcohols, Phenols, and Thiols	3	25	26	51
8	Ethers and Epoxides	6	15	23	38
9	Aldehydes and Ketones	10	29	22	51
10	Carboxylic Acids and Their Derivatives	8	36	27	63
11	Amines and Related Nitrogen Compounds	14	22	23	45
12	Spectroscopy and Structure Determination	9	18	30	48
13	Heterocyclic Compounds	3	8	19	27
14	Synthetic Polymers	3	16	23	39
15	Lipids and Detergents	4	9	20	29
16	Carbohydrates	6	15	37	52
17	Amino Acids, Peptides, and Proteins	9	20	41	61
18	Nucleotides and Nucleic Acids	3	8	26	34
	Totals	125	362	472	834
	Average per chapter	7	20	26	46

The Individual Chapters

The next section of this instructor's manual briefly discusses each text chapter. Priorities have been assigned to the various sections, in case time is a factor and all sections cannot be covered. Priority A refers to those sections that should be covered; Priority B pertains to those sections that might be (1) optional, (2) covered by students on their own, or (3) covered only in part. You will have to decide how you want to handle the "A Word About" sections, depending on your own and your students' interests. We note that almost no problems in the text are based on the material in the "A Word About" sections.

Introduction to the Student (5 pages, 8 sections)

No lecture on this material is necessary, although it is customary during the first lecture, when students are getting settled, to give them some idea of what the subject is about and what they can expect. As you no doubt are aware, a major problem in the "nonmajor" organic course is arousing and maintaining student interest and convincing students that some knowledge of organic chemistry is relevant to their own particular specialty. This introduction, supplemented with your own experience, may help. It should at least be assigned as optional reading.

Chapter 1 Bonding and Isomerism (35 pages, 18 sections, 2–3 lectures)

Priority A: Sections 1.2–1.18
B: Section 1.1

This is an important chapter, and students' future success in the course may well depend on their grasp of the fundamentals discussed here. Sections 1.1 and 1.2 review material that all students should have had in the freshman course. These sections can be assigned as outside reading or quickly reviewed during the first lecture. One should be able to start with Section 1.3, the formation of covalent bonds by carbon atoms.

Section 1.4 includes a definition of carbon radicals, to be used in Chapter 2 when discussing halogenation of alkanes. In Example 1.10 in Section 1.7, the idea of isomerism is introduced and then amplified in the following section. It is important that students be aware of electron counting and the use of curved arrows very early, and these ideas are introduced first in Section 1.6 and again in Sections 1.11 to 1.13. Although this is a review of freshman chemistry, it is worth taking the time to cover these sections well because the concept of formal charge is essential when we later write reaction mechanisms. Problems 1.45 to 1.50 at the end of the chapter reinforce these concepts.

Sections 1.14 to 1.16 introduce orbitals and sigma bonds; pi bonds are left until Chapter 3, where they are needed. In Section 1.17, the terms *acyclic*, *carbocyclic*, and *heterocyclic* are defined. Although there is no need to discuss the specific examples in Figures 1.12 to 1.14, some discussion of Table 1.6 (Section 1.18), which introduces the main functional groups approximately in the sequence in which they will be discussed, is worthwhile. The idea is that students should gradually become familiar with all these groups through seeing them over and over during the course.

Students should be expected to do all the problems at the end of this chapter. The objective of most of the Additional Problems is obvious; it is worth pointing out, however, that the objective of Problems 1.43 and 1.44 is *not* to learn the structures of the particular natural products but to understand the meaning of abbreviated structural formulas.

Chapter 2 Alkanes and Cycloalkanes; Conformational and Geometric Isomerism

(32 pages, 13 sections, 2–3 lectures)

- Priority A: Sections 2.1–2.5; 2.8–2.13
 B: Sections 2.6, 2.7; “A Word About” 1, 2;
 “A Closer Look At” 1,2

This chapter introduces systematic organic nomenclature and the concepts of conformational and *cis-trans* isomerism. Sections 2.1 to 2.5 cover the structure and nomenclature of alkanes and are essential. Through examples toward the end of Section 2.3 and again in Section 2.5, we anticipate the common student errors in naming.

Sections 2.6 and 2.7 are descriptive and need not take much class time. Sections 2.8 and 2.9 describe conformations of alkanes and cycloalkanes. The concept of conformation is fundamental to organic chemistry and should be covered thoroughly. *Cis-trans* isomerism is introduced in Section 2.10 in the context of cycloalkanes, where it is easy for students to visualize; the concept is reinforced with alkenes in Chapter 3.

Section 2.11 is a vehicle for understanding the relationship between various types of isomers, as summarized in Figure 2.5. Finally, Sections 2.12 and 2.13 deal with reactions of alkanes. Most important here is the concept of a reaction mechanism, as discussed in Section 2.3. If you so desire, this material may be supplemented with a discussion of energy diagrams, although energy diagrams are introduced formally in Chapter 3.

“A Word About” (hereafter abbreviated AWA) 1 (Isomers, Possible and Impossible) shows that not all organic structures are possible, even if we adhere to the correct valence rules. The particular example is limited by the ratio of surface area to volume, and the analogy with limits to growth in biological forms should interest students. AWA 2 (Methane Marsh Gas, and Miller’s Experiment) deals with descriptive aspects of methane chemistry and introduces briefly the subject of chemical evolution.

“A Closer Look At” (hereafter abbreviated ACL) 1 (Natural Gas) provides Web activities and questions related to material introduced in Section 2.6. It can be used to initiate activities related to the broader topic of how we use natural resources to satisfy our energy needs. ACL 2 (Hydrogen Bonding), associated with Section 2.7, can be used to examine questions ranging from “why is ice less dense than liquid water” to “why do oil spills float on water.”

Chapter 3 Alkenes and Alkynes

(46 pages, 21 sections, 4–6 lectures)

- Priority A: Sections 3.1–3.10; 3.14–3.21
 B: Sections 3.11–3.13; AWAs 3–5; ACL 3

In this, the book's longest chapter, students encounter a substantial number of reactions for the first time. The introductory sections on nomenclature are more thorough than those in most short organic texts, mainly because we anticipated special cases that students often ask about.

Next, the pi bond model is introduced as a way of rationalizing some empirical facts about double bonds (Section 3.3). This approach, rather than the reverse, emphasizes the sequence of experiment first, theory next (followed by new experiments to test the theory) that is so prevalent in all realms of science. *Cis-trans* isomerism in alkenes then follows as an experimental corroboration of theory (Section 3.5).

Addition reactions are introduced first as empirical observations (Sections 3.6 to 3.8); only later are their mechanisms discussed (Sections 3.9 and 3.10) as a way of rationalizing experimental results.

Sections 3.11 and 3.12, new in this edition, give a brief introduction to the thermodynamics and kinetics of organic reactions and the use of reaction energy diagrams. These sections, as well as Section 3.13 (hydroboration-oxidation), can be omitted if you consider them too specialized for your students. If you do omit them, do not assign Problems 3.52, 3.53b, 3.59e, and 3.61 at the end of the chapter. Catalytic hydrogenation is covered in Section 3.14.

Additions to conjugated systems (Section 3.15) include electrophilic additions, resonance in allylic cations, and the Diels-Alder reaction. You may consider the Diels-Alder reaction too specialized. If so do not assign Problems 3.50 and 3.51 at the end of the chapter. The material on dienes is followed by a section (3.16) on applied organic chemistry, the free-radical polymerization of ethylene. It is worthwhile to call attention to practical aspects of organic chemistry early in the course. However, a more thorough treatment of synthetic polymers is deferred to Chapter 14, at which point students are better able to handle more complex structures.

Section 3.17 covers several diverse aspects of alkene oxidation: the permanganate test, ozonolysis, epoxidation (dealt with again in Chapter 8), and combustion. If you omit any of these topics because of time constraints, you may not want to assign some or all of Problems 3.55, 3.56, 3.59f, 3.59g, and 3.59h.

Sections 3.18 to 3.21 cover the structure and reactions of alkynes. Sections 3.18 to 3.20 provide a chance to review pi bonds and addition reactions; Section 3.21 introduces a new idea, the acidity of $\text{C}-\text{H}$ bonds.

AWA 3 (The Chemistry of Vision) illustrates with a biological example the importance of *cis-trans* isomerism (Section 3.5). AWA 4 (Ethylene: Raw Material and Plant Hormone) illustrates the tremendous importance of ethylene as an industrial chemical. You might want your students to write out equations for the transformation of ethylene to the other industrial organic chemicals shown in Figure 3.10. AWA 5 (Petroleum, Gasoline, and Octane Number), although largely descriptive and suitable for outside reading, is worth some class time as another practical aspect of organic chemistry.

ACL 3 (Petroleum) provides activities that supplement and complement material introduced in Section 3.21 and AWA 5.

Chapter 4 Aromatic Compounds

(30 pages, 13 sections, 2–3 lectures)

Priority A: Sections 4.1–4.6; 4.8–4.12
 B: Sections 4.9, 4.13; AWAs 6, 7; ACL 4

The introduction is historical and can be covered as assigned reading. Section 4.1 presents empirical facts about aromatic compounds that then are explained by progressively more precise theories (Sections 4.2 to 4.4). This is a good place to point out to students that the science is dynamic and evolving, not static or fixed in its ideas.

Sections 4.5 and 4.6 cover the symbols for and nomenclature of benzenoid compounds. Several examples illustrate the important difference between the phenyl and benzyl groups.

Section 4.7 (resonance energy) can be omitted, although it is valuable in that it gives some experimental meaning to the rather abstract concept of resonance. It is useful to use energy diagrams if you do include this section. If you omit this section, do not assign Problem 4.25.

Section 4.8, which presents electrophilic aromatic substitution empirically, is followed by a mechanistic discussion (Sections 4.9 to 4.11). Although it is possible to present the orientation rules and rate effects of substituents empirically (Table 4.1), it is much more satisfying to provide students with a mechanistic rationalization, as is done in Section 4.11. This section seems longer than it really is, mainly because of the space Equations 4.26 to 4.31 take up. If this material is too detailed for your students and you decide to skip it, do not assign Problems 4.29 and 4.30, and possibly 4.36. Section 4.12, on the

synthetic implications of orientation rules for multistep aromatic synthesis, can be covered whether or not you omit Section 4.11.

Section 4.13 extends aromaticity to polynuclear aromatic hydrocarbons. At least the structures should be mentioned, even if the substitution reactions are omitted.

AWA 6 (Polycyclic Aromatic Hydrocarbons and Cancer) describes the biological (that is, carcinogenic) properties of polynuclear aromatics as well as the toxicity difference between benzene and toluene. AWA 7 (C₆₀, an Aromatic Sphere: The Fullerenes) describes the interesting new research area of fullerenes, which students with even the limited level of understanding of organic chemistry they have at this stage of the course can appreciate.

ACL 4 (Polycyclic Aromatic Hydrocarbons) provides activities associated with Section 4.13 and can be used to involve students with several topics of contemporary interest, including carcinogenicity or carbon materials in interstellar space.

Chapter 5 Stereoisomerism (33 pages, 12 sections, 2–3 lectures)

Priority A: All sections; AWA 8

B: AWA 9; ACL 5

This is an important chapter, and we recommend that it be covered completely. Although the material can be taught without the *R-S* or *E-Z* nomenclature systems, the systems are useful pedagogically because they help students visualize molecules in three dimensions. If students use the main features of these systems properly, then we *know*, as teachers, that they really do “see” the structures as they should be seen.

Sections 5.1 to 5.2 introduce important terms such as *chiral*, *achiral*, *enantiomers*, *nonsuperimposable mirror images*, *stereogenic center*, *stereogenic carbon*, and *plane of symmetry*. Section 5.3 covers configuration and the *R-S* convention. Students sometimes have difficulty selecting the observation point for applying these rules; we used two dashed wedge–solid wedge conventions for doing this. Students may also need special help in assigning priority orders to groups with multiple bonds (C=C, C=O, C≡C, etc.), covered in our rule 3. We give a worked example (Example 5.4), but you may also want to help students through Problem 5.9. The *E-Z* convention (Section 5.4) is easy compared with the *R-S* convention because there is no observation point to decide on.

At this stage in the chapter, students should understand some of the principles of chirality and are ready for a diversion to its experimental observation in optical activity (Section 5.5). AWA 8 is a historical account of Pasteur's experiments and the tetrahedral carbon proposal of van't Hoff and LeBel. There are lessons to be learned from this account—about how science is really done and how it develops—and you may want to discuss them in class.

Section 5.6 describes how enantiomers are alike and how they differ. Fischer projections are introduced next (Section 5.7), partly because their manipulation reinforces the relationship between enantiomers and partly because they are useful in dealing with molecules with more than one stereogenic center (Sections 5.8 and 5.9). They also facilitate discussions of diastereomers and meso forms.

Section 5.10 (like Section 2.11) deals with the classification of stereoisomers. Using specific examples of isomeric pairs, we contrast conformational with configurational, chiral with achiral, and enantiomers with diastereomers. This brief section thus pulls together major concepts of stereoisomerism. The final sections deal very briefly with applying stereochemical principles to chemical reactions (Section 5.11) and to the resolution of a racemic mixture (Section 5.12).

AWA 9 (Enantiomers and Biological Activity) can be used to introduce the importance of handedness to biological phenomena such as smell, taste and drug efficacy.

ACL 5 (Thalidomide) provides students with a closer look at this issue within the context of a real world problem. This activity can be used to introduce some of the chemical problems associated with modern drug development.

Molecular models are expensive, perhaps too expensive for each student to own a set. Yet working with models is so helpful in understanding Chapter 5 that we urge that models somehow be made generally available to students, especially when they study this chapter.

Chapter 6 Organic Halogen Compounds; Substitution and Elimination Reactions

(25 pages, 9 sections, 2–3 lectures)

Priority A: Sections 6.1–6.7; 6.9
B: Sections 6.8; AWAs 10–12

This chapter immediately follows the chapters on stereochemistry so that the important interplay between three-dimensional molecular structure and reaction mechanism can be illustrated. Nucleophilic substitutions are first introduced as empirical facts (Sections 6.1 and 6.2). The possible competition between substitution and elimination reactions and the failure of substitutions to occur with certain substrates are also introduced as empirical facts (Equations 6.4 to 6.7) that must then be explained by a satisfactory theory (reaction mechanism).

Sections 6.3 to 6.6 explain nucleophilic substitutions mechanistically. The discussion of Figures 6.1 and 6.2 (Sections 6.4 and 6.5) can be omitted if you chose not to discuss reaction energy diagrams when they were introduced in Chapter 3. The nucleophilic substitution discussion is followed by a discussion of elimination mechanisms (Section 6.7). In Section 6.8, the two reactions are compared so that the empirical observations described in the early sections of the chapter can be rationalized.

Section 6.9 is largely descriptive and can be assigned without classroom discussion, if necessary. It describes practical applications of polyhalogen compounds that are likely to interest most students.

AWA 10 (S_N2 Reactions in Nature: Biological Mechanisms) can be used to show that the mechanisms by which organic reactions occur are the same, whether conducted in the laboratory or living systems. AWAs 11 and 12 can be covered as assigned reading if lecture time is limited. AWA 11 (CFCs, the Ozone Layer, and Trade-Offs) can lead to a class discussion on the impact of an industrial society on the environment. AWA 12 (Halogenated Organic Compounds from the Sea) is descriptive and can be assigned without classroom discussion.

Chapter 7 Alcohols, Phenols, and Thiols

(27 pages, 17 sections, 2–3 lectures)

Priority A: Sections 7.1–7.9; 7.12; 7.17
B: Sections 7.10, 7.11, 7.13–7.16; AWA 13–16

Following classification and nomenclature (Sections 7.1 to 7.3), the important effect of hydrogen bonding on alcohol and phenol boiling points and solubility in water is described (Section 7.4). Because hydrogen bonding comes up again in later parts of the text, it is important that students understand the concept well.

Section 7.5 reviews the principles of acidity and basicity. Despite the fact that these topics are usually covered thoroughly in general chemistry courses, most students will benefit from further classroom discussion of this section. Section 7.6 applies these ideas to the acidity of alcohols and phenols

and also includes the important effect of electron-withdrawing and electron-donating substituents on acidity, ideas that are used later in Chapters 10 and 11.

The brief Section 7.7, on the basicity of the hydroxyl group, is a necessary prelude to the dehydration of alcohols (Section 7.8). This material reinforces the Chapter 6 discussion of elimination mechanisms. Similarly, the conversion of alcohols to alkyl halides (Section 7.9) is an opportunity to reinforce nucleophilic substitution mechanisms.

The preparation of alkyl halides from alcohols using thionyl chloride or phosphorus halides (Section 7.10) can be omitted, although this reaction does provide the background for preparing acyl halides (Chapter 10). If you do omit Section 7.10, do not assign Problems 7.44c and 7.44d.

We think Section 7.11 is an important little section because it specifically addresses a question many students have: Why can't the OH group of phenols be replaced in the same way that the OH group of alcohols can? However, the section can be omitted if time is a factor.

Oxidation of alcohols (Section 7.12) is a key reaction and is an opportunity to present again the structures of aldehydes, ketones, and carboxylic acids. The material in Section 7.13 (polyhydric alcohols) is descriptive and can be assigned reading. Students will need to know the structures of ethylene glycol and glycerol later.

Section 7.14 provides a chance to reinforce electrophilic aromatic substitution. Section 7.15 introduces quinones and Section 7.16 describes the use of hindered phenols as antioxidants. You can omit these sections, although if your students will later be studying biochemistry, they should at least be introduced to quinone structures.

Thiols are an important class of compounds, and some knowledge of their chemistry is needed in discussing protein structure (Chapter 17); Section 7.17 is an opportunity to compare thiols' reactions with those of alcohols.

AWAs 13 (Industrial Alcohols) and 14 (Biologically Important Alcohols and Phenols) are descriptive but can benefit from some classroom discussion. AWA 15 (Quinones and the Bombardier Beetle) provides an interesting example of oxidation of a hydroquinone to a quinone with biological consequences. AWA 16 (Hair, Curly or Straight) is a fun example of thiol-disulfide interconversion that students can enjoy on their own.

Chapter 8 Ethers and Epoxides

(19 pages, 9 sections, 1–2 lectures)

- Priority A: Sections 8.1–8.5, 8.7, 8.8
 B: Sections 8.6, 8.9; AWAs 17–18; ACL 6

Sections 8.1 to 8.4 cover nomenclature, hydrogen bonding, and the solvent properties of ethers. It may seem strange to introduce the Grignard reagent in a chapter on ethers (Section 8.4), but there are several advantages to doing so. First, the Grignard reagent illustrates very nicely the importance of solvation and the effectiveness of ethers in this regard. It also allows us to add to the chapter a few reactions that do not overtax students. Another logical place for introducing Grignard reagents is with alkyl halides (Chapter 6), but that chapter is already burdened with many reactions and the complexities of nucleophilic substitution and elimination mechanisms. Grignard reagents are sometimes introduced in a chapter on aldehydes and ketones, but our chapter on those subjects (Chapter 9) has very many reactions for students, so the ether chapter is a good place for the Grignard reagent. Furthermore, we can use it right away, later in the chapter, in the reaction with ethylene oxide, and then again in the two following chapters. The introduction of organolithium compounds is not essential (Section 8.4), but can be used to reinforce the importance of organometallics as a family of compounds.

Section 8.5, on the preparation of ethers, once again provides a chance to reinforce aliphatic nucleophilic substitution mechanisms, as does Section 8.6 on ether cleavage. Epoxides (structure,

preparation, and reactions) are covered in Sections 8.7 and 8.8. They provide an excellent opportunity to describe practical applications of organic chemistry.

Section 8.9 is descriptive. Students will need to know the structures for tetrahydrofuran and tetrahydropyran in connection with carbohydrate chemistry (Chapter 16). The other material in this section can be omitted or can be expanded on in connection with the important biological process of ion transport across cell membranes.

AWA 17 (Ether and Anesthesia) is descriptive and requires no classroom discussion. AWA 18 (The Gypsy Moth's Epoxide) is also descriptive and deals with biological applications of epoxide chemistry. ACL 6 (MTBE) can be used to explore risk-benefit issues associated with the use of a commodity chemical.

Chapter 9 Aldehydes and Ketones

(32 pages, 19 sections, 3–4 lectures)

- Priority A: Sections 9.1–9.3; 9.5–9.7; 9.9 and 9.10; 9.12–9.15;
9.17–9.19
- B: Sections 9.4, 9.8, 9.11, 9.16; AWA 19

The introduction and Section 9.1 on nomenclature are followed by a description (Section 9.2) of industrial aldehydes and ketones (formaldehyde, acetaldehyde, and acetone). The equations for these industrial syntheses are not required, but the three synthetic routes reviewed in Section 9.3, each of which has been discussed in a previous chapter, are important because they form the basis of several synthesis problems. Section 9.4 requires no classroom time.

Sections 9.5 and 9.6 provide a key to understanding carbonyl chemistry, and the principles set forth there are explained in some detail in the following section (9.7) on hemiacetals and acetals. The importance of these three sections cannot be overstated. Although Section 9.7 stresses acetal *formation*, the important reverse process, *acetal hydrolysis*, is also briefly described, and it may be a good idea to work through Example 9.2 and Problem 9.12 in some detail in class. The brief section (9.8) on carbonyl hydration can be optional.

Sections 9.9 to 9.11 continue with other examples of nucleophilic additions to the carbonyl group. The reaction with nitrogen nucleophiles (Section 9.11) is sometimes difficult for students at this level, particularly since amines have not yet been discussed. If you include this section, you may want to discuss only the reaction with primary amines (important in biology) and omit the other ammonia derivatives. If you do, do not assign Problems 9.32e, 9.32f, 9.32j, 9.37b, 9.37e, 9.37f, 9.43c, 9.43d, 9.43e.

Sections 9.12 and 9.13 treat, respectively, the reduction and oxidation of carbonyl compounds. The reduction mechanism is just another example of nucleophilic addition, but the oxidation mechanisms are somewhat complex and are not given here, although the material can be supplemented if you think that this is important for your students.

Sections 9.14 to 9.16 cover keto-enol tautomerism. Section 9.16, deuterium exchange, can be omitted, although we think it gives students concrete experimental evidence for the fairly difficult concept of tautomerism.

Sections 9.17 to 9.19 cover the aldol condensation. This is one of the more complex reactions for students and so requires careful presentation in lecture.

AWA 19 (Water Treatment and the Chemistry of Enols and Enolates) can be used to extend the discussion of enolate chemistry and initiate a discussion of environmental chemistry (also see AWA 20 in Chapter 10).

Chapter 10 Carboxylic Acids and Their Derivatives

(40 pages, 22 sections, 3–4 lectures)

Priority A: Sections 10.1–10.10; 10.13, 10.15–10.21

B: Sections 10.11, 10.12, 10.14, 10.22; AWAs 20, 21; ACL 7

This chapter continues the chemistry of carbonyl compounds. The introduction and Section 10.1 on nomenclature include substituted, unsaturated, hydroxy and keto, and dicarboxylic acids. Section 10.2 contains a brief descriptive section on the physical properties of acids and can be assigned as outside reading.

Sections 10.3 to 10.6 deal with factors that affect acid strength and the reaction of acids with strong bases. Section 10.6 includes nomenclature of salts, which, if mastered, will help students with the ester nomenclature that comes just a little later in the chapter. The chemistry of acids is concluded in Section 10.7 with a section on their preparation.

Section 10.8 is a brief introduction to acid derivatives and to what follows in the rest of the chapter. Ester nomenclature and properties (Section 10.9) is followed by Fischer esterification (Section 10.10) and its mechanism (Section 10.11). The mechanistic discussion is placed in a separate section so that you can omit it if you feel that this is more chemistry than your students need to know. If you omit Section 10.11, do not assign Problem 10.47.

Section 10.12 on lactones is descriptive and needs no class time. Section 10.13 covers saponification of esters, and the mechanistic discussion here may be sufficient for your group of students.

Sections 10.14 to 10.16 describe three other reactions of esters. The reaction of esters with ammonia (Section 10.14) is optional—it is picked up, in any event, in the review section (10.21) and, in particular, in Table 10.5. Do not assign problems 10.50b and 10.53d if you omit this section (or at least postpone them until the chapter is completed).

Section 10.15, on the reaction of esters with Grignard reagents, is also optional, although it reinforces the discussion of Section 9.9. If you do omit this section, do not assign Problems 10.49c and 10.51. The chemistry in Section 10.16 reinforces the discussion of Section 9.12. If you omit this section, do not assign Problems 10.49d and 10.54f.

Section 10.17 generalizes the mechanisms of the reactions discussed to this point in the chapter and explains the need for activated acyl compounds such as halides, anhydrides, and, in nature, thioesters. This section, which is somewhat unique, provides a rationale for studying acyl halides and anhydrides. Sections 10.18 and 10.19 then present the usual chemistry of these acid derivatives.

Section 10.20 on amides provides necessary background for Chapter 17 (proteins); it is important to discuss it in some detail. Section 10.21, particularly Table 10.5, ties together what may seem, to students, a rather substantial number of reactions presented in this chapter.

The chapter ends on a similar note to the previous chapter, with the Claisen condensation (analogous to the aldol in Chapter 9). It has the great benefit of emphasizing the similarity between two classes of carbonyl compounds and reviewing enolate anions and their role in nucleophilic additions. But the chemistry is somewhat complex, so you may want to omit this section. If you do, do not assign Problems 10.57 to 10.59.

AWA 20 (Green Chemistry and Ibuprofen: A Case Study) can be used to initiate a discussion of environmental chemistry. ACL 7 (Green Chemistry) provides Web activities that can be used to expand a discussion of environmental chemistry. AWA 21 (Thioesters, Nature's Acyl-Activating Groups) is important for students with biological interest, and you may want to discuss it in class.

Chapter 11 Amines and Related Nitrogen Compounds

(28 pages, 13 sections, 2–3 lectures)

Priority A: Sections 11.1–11.8; 11.10–11.13
 B: Section 11.9; AWA 22

This is the last chapter dealing with the major functional groups. Students who thoroughly understand the first 11 chapters of the book will be able to go on to an elementary biochemistry course with a good chance of success. For abbreviated one-quarter courses, coverage of this chapter should give nonmajors a good background in organic chemistry.

Sections 11.1 to 11.2 cover amine classification and nomenclature. We included not only the common and IUPAC names but the relatively new CAS system because of its simplicity and ease of use. These sections are followed by a descriptive section (11.3) that requires little classroom discussion. Sections 11.4 and 11.5 cover the preparation of amines, providing an opportunity to review and build on nitrogen chemistry covered in earlier chapters. The basicity of amines in terms of the pK_a 's of the conjugate ammonium ions is discussed in Section 11.6, followed in Section 11.7 by a comparison with amides and in Section 11.8 by the reaction with strong acids to form amine salts and their use in separations.

Section 11.9 on chiral amines as resolving agents is an opportunity to review the distinction between enantiomers and diastereomers, but it can be omitted if necessary. Acylation of amines (Section 11.10) is a chance to examine the reaction of acid derivatives with amines from a different perspective. A brief section (11.11) on quaternary ammonium compounds follows.

Sections 11.12 and 11.13 discuss aromatic diazonium compounds, their use in aromatic synthesis, and their coupling reactions to form azo dyes. AWA 22 (Alkaloids and the Dart-Poison Frogs) describes amines that play an interesting role in predator-prey relationships.

Chapter 12 Spectroscopy and Structure Determination

(35 pages, 6 sections, 2 lectures)

Priority A: Sections 12.1–12.6
 B: AWA 23; ACL 8

The role of spectroscopy in the short organic course has long been debated. Some instructors think the subject is unnecessary or inappropriate for nonmajors; others think that it is very important and a useful framework for discussing organic structures. We placed the subject in a prominent place—immediately following the last chapter on the major functional groups—and emphasized the role of spectroscopy in determining organic structures. Those who wish to use the chapter should find it a good mechanism for reviewing organic structure. For those who wish to omit spectroscopy, we purposely refrained from including any spectroscopic questions in subsequent chapters.

The emphasis here is on the practical, structure-solving utility of spectroscopic methods. Theory is only briefly discussed, so you may want to supplement what is presented.

Following the introduction, a very brief outline of the principles of spectroscopy is given in Section 12.1. The meat of the chapter is in Section 12.2 on ^1H NMR spectroscopy because it is this methodology that has had the most profound effect on organic structure determination in the last 40 plus years; also, it is perhaps the most useful section pedagogically.

The treatment of ^{13}C NMR (Section 12.3) nicely supplements the ^1H NMR section. It is followed by infrared (Section 12.4), visible and ultraviolet (Section 12.5), and mass (Section 12.6) spectroscopy.

For your convenience in assigning problems at the end of the chapter, they have been classified according to spectroscopic method.

AWA 23 (NMR in Biology and Medicine) describes the use of NMR in studying intact bodily fluids as well as magnetic resonance imaging (MRI). ACL 8 (Mass Spectrometry and Carbon Dating) can be used to illustrate a modern application of mass spectrometry (Section 12.6).

Chapter 13 Heterocyclic Compounds

(21 pages, 8 sections, 1–2 lectures)

Priority A: Sections 13.1–13.3; 13.5–13.7
 B: Sections 13.4, 13.8; AWAs 24, 25; ACL 8

Heterocycles form the largest class of organic compounds, yet they are often entirely neglected in short organic texts. This chapter corrects that deficiency, at least with regard to aromatic heterocycles.

Our treatment is somewhat unconventional in that it begins with six-membered heterocycles and then proceeds to five-membered examples. We did so for pedagogical reasons. Students recognize benzene as aromatic and can therefore easily understand the similar electronic arrangement in pyridine, where one CH of benzene is replaced by N. Only later do they encounter cases, in the five-membered rings, where one heteroatom donates *two* electrons to the aromatic pi system.

Following a brief introduction, the structure, bonding, and basicity of pyridine are described (Section 13.1). Next, Section 13.2 takes up the chemistry of pyridine—electrophilic and nucleophilic substitution, oxidation, and reduction—and the existence of this ring in natural products.

Section 13.3 outlines the scope of other six-membered heterocycles: fused-ring pyridines (quinolines and isoquinolines), rings with two or more nitrogens, and rings with oxygen (pyrylium ions). Next we take up five-membered heterocycles, first the simple cases of furan, pyrrole, and thiophene in Sections 13.4 and 13.5, then the azoles with two heteroatoms (Section 13.6) and fused-ring examples (indoles and purines) in Section 13.7. Thus the order of the chapter is logical, proceeding from the familiar to the unknown.

AWAs 24 (Porphyrins: What Makes Blood Red and Grass Green?) and 25 (Morphine and Other Nitrogen-Containing Drugs) are both largely descriptive and can be read by students on their own, although each essay can profit from classroom discussion—AWA 24 as an example of biologically important organometallic compounds and AWA 25 as an example of a contribution of synthetic organic chemistry to medicine.

Chapter 14 Synthetic Polymers

(28 pages, 9 sections, 1–2 lectures)

Priority A: Sections 14.1–14.4; 14.6–14.9
 B: Sections 14.5, 14.7; AWAs 26–28; ACL 9

Polymers are one of the most important industrial applications of organic chemistry. To focus attention on them, we devote this separate chapter to their synthesis and properties. The chapter also reviews a lot of simple functional group chemistry.

Following the introduction and Section 14.1, we take up free-radical chain-growth polymerization in some detail (Section 14.2). In Chapter 3 (Section 3.16), the free-radical polymerization of ethylene was described, but here we offer a more general treatment that includes chain-transfer and cross-linking.

Cationic and anionic chain-growth polymerization follow in Sections 14.3 and 14.4 and can be used to review carbocations, electrophilic and nucleophilic additions, resonance, S_N2 displacements, and so on. Section 14.5 on stereoregular polymers points out once again the importance of stereochemistry.

The section can be omitted, however, without risk to discussions of the remaining sections. If you do omit this section, do not assign Problems 14.25 to 14.27. Section 14.6 on natural and synthetic rubber is an opportunity to review 1,4- and 1,2-addition and *cis-trans* isomerism.

The idea of copolymers is introduced in Section 14.7; examples of chain-growth polymers are used, but the section is also a prelude to the rest of the chapter, which deals with step-growth polymers, almost all of which are copolymers. Dacron and nylon are used as prime examples of step-growth polymers (Section 14.8). The more complex cases of polyurethanes, Bakelite, urea-formaldehyde polymers and epoxy resins are taken up in Section 14.9.

AWA 26 (Polyacetylene and Conducting Polymers) focuses on the topic for which the 2000 Nobel Prize in chemistry was awarded. AWA 27 (Degradable Polymers) addresses a topic of contemporary interest and could lead to an interesting class discussion. AWA 28 (Aramids, the Latest in Polyamides) can easily be handled as assigned reading because it is largely descriptive. ACL 9 (Nylon) provides a nice supplement to material introduced in Section 14.8.

Chapter 15 Lipids and Detergents

(22 pages, 9 sections, 1–2 lectures)

Priority A: Sections 15.1–15.5

B: Sections 15.6–15.9; AWA 29, 30

This is the first of four chapters on biologically important molecules. In all these chapters, attention is on the structures and reactions—in short, the organic chemistry rather than the biochemistry—of these substances.

The introduction defines lipids. Section 15.1 describes fats and oils, their structural similarities and differences; Section 15.2 covers hydrogenation, which converts one to the other.

The discussion of saponification (Section 15.3) leads naturally to a description of soaps (Section 15.4) and synthetic detergents (Section 15.5). The final four sections on phospholipids (Section 15.6), prostaglandins (Section 15.7), waxes (Section 15.8), and terpenes and steroids (Section 15.9) are largely descriptive. The extent to which you wish to discuss these topics in class will depend on you and your students' interests; all four sections can be handled as recommended reading. Section 15.10 is perhaps the most important one.

AWA 29 (Commercial Detergents) and AWA 30 (Prostaglandins, Aspirin, and Pain) are entirely descriptive and need not take class time.

Chapter 16 Carbohydrates

(31 pages, 17 sections, 2–3 lectures)

Priority A: Sections 16.1–16.13

B: Sections 16.14–16.17; AWA 31, 32

Because no new functional groups are introduced in this chapter, and most of the chemistry involves the carbonyl and hydroxyl groups, this chapter can be taken up with virtually complete comprehension any time after the students have completed Chapter 9 (Aldehydes and Ketones). The subject matter reinforces carbonyl chemistry, particularly hemiacetal and acetal formation and hydrolysis. If you feel that your students need a break between two chapters with a lot of reactions (Chapters 9 and 10), then this is a good thing to do. The chapter has been located where it is so that all four chapters on biologically important molecules appear in sequence.

The principal goal of this chapter is to acquaint students with the main features of carbohydrate structure. They should obtain some understanding of the way monosaccharides are linked together in di- and polysaccharides.

Sections 16.1 to 16.3 take up nomenclature and stereochemistry, including the use of Fischer projection formulas. Cyclic structures (Section 16.4) and experimental evidence for them (mutarotation, Section 16.5) come next, followed by conventions for representing the structures (Sections 16.6 and 16.7). The manipulation of Fischer projections to Haworth projections is facilitated by Figure 16.2, but students may need help with this idea, using molecular models.

Sections 16.8 to 16.10 describe reactions of monosaccharides, which in a sense are a review of carbonyl and hydroxyl group chemistry. Pedagogically this is useful to do because the carbohydrate structures look very complicated to beginning students; the reactions in these sections, however, are quite simple and familiar to students.

Section 16.11 (glycosides) lays the chemical groundwork for understanding the structures of di- and polysaccharides, which follow in Sections 16.12 and 16.13. Much of the material in the latter sections is descriptive, however, and only brief coverage of the essential features of the structures is necessary in lecture.

The final four sections describe modified carbohydrate structures. Sugar phosphates (Section 16.14) and deoxy sugars (Section 16.15) are encountered again in the chapter on nucleic acids (Chapter 18) and can be omitted here or deferred. Sections 16.16 and 16.17, on amino sugars and ascorbic acid, are also descriptive and can be omitted or covered by outside reading. If you omit these four sections, do not assign Problem 16.48. AWA 31 (Sweetness and Sweeteners) includes a synthesis of saccharin that can be instructive to discuss in class because it reviews some aromatic and acid derivative chemistry. AWA 32 (Fat Substitutes from Carbohydrates) is descriptive and could be used (along with AWA 31) to initiate a discussion of contemporary issues in food science.

Chapter 17 Amino Acids, Peptides, and Proteins

(35 pages, 15 sections, 2–3 lectures)

Priority A: Sections 17.1–17.4; 17.6; 17.8–17.15
 B: Section 17.5; 17.7; AWAs 33–34

This is a long chapter, but substantial parts are descriptive and can be handled as outside reading. Definitions and the stereochemistry of amino acids are introduced in Section 17.1. If students are expected to know the structures of the amino acids (Table 17.1), then some discussion of their structures in class is necessary. Table 17.1 presents the structures, organized according to sidechain functional groups.

The acid-base properties of amino acids (Sections 17.2 and 17.3) are important, although one can afford to be somewhat more qualitative than the text. Section 17.4, on electrophoresis, introduces separations based on pH. Section 17.5, on reactions of amino acids, introduces no new chemistry but reminds students of reactions already studied that are needed in later sections.

The ninhydrin reaction (Section 17.6) can be omitted; if you do so, do not assign Problem 17.35.

Sections 17.7 and 17.8 provide the basis for understanding protein structures and should be discussed thoroughly in class. Section 17.9 briefly introduces the topic of proteins. Sections 17.10 and 17.11 on primary protein structure, and the section on peptide synthesis that follows (17.13), form the heart of the chapter and require a full discussion in class. The rest of the chapter is mainly descriptive, however, and the extent to which you discuss it in lecture will depend on your interests and those of your students.

AWA 33 (Some Naturally Occurring Peptides) and AWA 34 (Protein Sequencing and Evolution) are descriptive; most students can read them with pleasure and without difficulty. ACL 10 (Nobel Laureates and Protein Chemistry) directs students to an interesting website that can be used not only in connection with this chapter, but many other chapters of this book.

Chapter 18 Nucleotides and Nucleic Acids (25 pages, 12 sections, 1–2 lectures)

Priority A: Sections 18.1–18.5; 18.8–18.12
B: Sections 18.6, 18.7; AWAs 35–37

This is a vast topic and one to which each student probably brings some degree of background information. This text emphasizes mainly the organic chemical aspects of the structures and reactions. Sections 18.1 to 18.5 cover the main structural features of nucleosides and nucleotides and the linking of the latter in DNA chains. One can go directly from there to base pairing and the double helix in Section 18.8 and Section 18.10 on RNA; Sections 18.6 and 18.7, on sequencing and synthesis of nucleic acids, are descriptive. Whether or not you cover the sections on DNA replication and PCR (Section 18.9), the genetic code (Section 18.11), and other nucleotides (Section 18.12) depends on how much time is available and how comfortable you feel with this material.

AWA 35 (DNA and Crime) deals with a topic of considerable current interest, as do AWA 36 (The Human Genome) and AWA 37 (Nucleic Acids and Viruses), which outlines some of the difficulties in finding antiviral agents for AIDS and other viral diseases. These three essays are descriptive and can profitably be read by students on their own, but they can also provide topics for stimulating class discussion. ACL 11 [The Polymerase Chain Reaction (PCR)] can be used to supplement the small amount of space devoted to this topic in Section 18.9.