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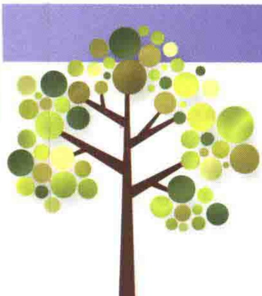
and Catherine J. Pears

Thrive in Biochemistry and Molecular Biology

Thrive in Bioscience | Revision Guides



Thrive in Biochemistry and Molecular Biology

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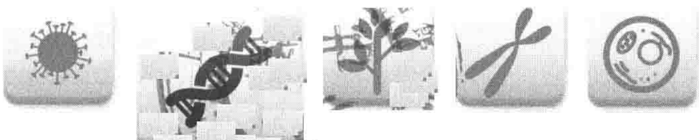

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Thrive in Bioscience | Revision Guides

Four steps to exam success

1 *Review the facts*

This book is designed to help your learning be quick and effective:

- Information is set out in bullet points, making it easy to digest
- Clear, uncluttered illustrations illuminate what is said in the text
- Key concept panels summarize the essential learning points

2 *Check your understanding*

- Try the questions at the end of chapters and online multiple-choice questions to reinforce your learning
- Download the flashcard glossary to master the essential terms and phrases

3 *Take note of extra advice*

- Look out for revision tips, and hints for getting those precious extra marks in exams

4 *Go the extra mile*

- Explore any suggestions for further reading to take your understanding one step further

Go to the Online Resource Centre for more resources to support your learning, including:

- Online quizzes, with feedback
- A Flashcard glossary, to help you master the essential terminology

online resource centre

www.oxfordtextbooks.co.uk/orc/thrive/

Using this guide

This book is designed to be an *aide memoire* and a quick check-up source rather than an authoritative text. You will need to have revised material from your lecture notes, textbooks, and recommended reading lists in order to get full value from this book. We have tried to include core material that is central to an understanding of biochemical processes. However, courses differ, so not all the material here may be covered in your course, and there may be aspects we haven't included here that you do need to know about. It is also worth checking out the other revision guides in this series on, for example, cell biology and genetics, according to your own course requirements.

The material is arranged into related sections, though of course there is cross-talk between aspects of biochemistry in the cell, so we have tried to cross-reference sections where relevant. Note that we have used italics to highlight enzymes—this does not imply that enzyme names are normally italicized, but it should help you to be able to identify the relevant enzyme in the general body of the text. We have highlighted important terms in bold and included a definition of these in the Glossary.

Sometimes it can be hard to remember all the points about a topic. We have broken the topics down into smaller chunks to make revision easier. In addition, it can help to learn the number of steps in a biochemical pathway, e.g. if you know that there are ten steps in glycolysis, this should help you to ensure that you don't miss out anything crucial.

Exam technique

When answering **short questions**, ensure that your answer is concise and precise, and that it contains all the information required but no waffle or irrelevant information. In some cases, it is OK to use bullet points, but not in others, so make sure you choose a format appropriate to your own university's exams. Although exam styles vary, examiners will always appreciate scientific accuracy, relevance, and logical argument.

We have included some sample exam questions in the book, with hints (we haven't given you worked answers as the text itself is in essence the answer—we have boiled the information down to the bare minimum). There are also multiple choice tests online linked to each section of the book, so you can check your progress in revision.

online resource centre Go to www.oxfordtextbooks.co.uk/orc/thrive/

For **multiple choice questions**, try to come up with the correct answer first, then check the answers given—be particularly careful when you have to identify correct combinations of answers.

> **e.g. Which of the following is true about eukaryotic translation?**
>
> i) The ribosome is made up of 40S and 60S subunits forming a 100S complex.
> ii) The ribosome is made up of 40S and 60S subunits forming an 80S complex.
> iii) The AUG start codon of the mRNA is initially located in the P site of the ribosome.
> iv) The AUG start codon of the mRNA is initially located in the A site of the ribosome.
> v) Peptide bond formation is mediated by an RNA enzyme (a ribozyme).
>
> **Answers:**
>
> A i, iv, v B i, iii, v C ii, iii, v D ii, iv, v E ii, iv
>
> (the correct answer is C)

When tackling **exam essays**, remember:

- Read the question carefully, and try to identify exactly what the examiner is asking for (e.g. is the question limited to prokaryotes or eukaryotes, or should you include both?). Are details of a single biochemical process required, or do you need to integrate material from various parts of your course to answer the question fully? If so, do you know all those topics well enough to provide a balanced answer?
- For a one-hour essay, spend at least five minutes planning at the start—it may seem scary when everyone else appears to have launched straight in, but your essay will be coherent and well-structured, and planning makes sure that you don't forget to include critical points, and that you can balance the material appropriately. Preparation is key here—it really helps if you have already thought out various different essay plans for every conceivable way a question could be asked on each topic, as this saves a lot of time in exams; the pressure is much less if you are confident that you have prepared thoroughly. There is no single correct way to plan an essay—some people make mind maps, others prefer lists, but do make sure that you don't waste time writing full prose (save that for the essay; you can use abbreviations as much as you like in a plan). As you are writing, do keep checking your plan to make sure you include everything you think important.
- Avoid waffle—every word needs to count so make sure it's scientific and conveys information quickly, clearly, and coherently. Do make sure you use technical terms correctly and spell scientific words carefully. Examiners are not

just looking for factual content but evidence that you understand the material. You can demonstrate this by using a clear essay structure (subheadings can really help guide the examiner in your thought processes—check if it's permitted at your institution) and by providing a cogent argument.
- Try to include an introduction, the core material, and if time, a rounded conclusion …
- The introduction should contain a definition of the key terminology of the question at the start of your answer. You can pick up marks quickly this way and begin the essay in a biochemically convincing manner. For example, 'DNA replication is the template-directed synthesis of a polymer of deoxyribonucleotides mediated by DNA polymerases involving formation of phosphodiester bonds, and is driven by a highly negative ΔG from PP_i hydrolysis …' sounds rather more scientific than 'DNA replication is important and happens in all cells every time they divide'—a statement that is equally true but much less biochemically precise. You can also set the scope of the essay, e.g. 'I shall discuss predominantly eukaryotic ATP synthesis pathways, but will touch on those in prokaryotes where appropriate …'

Paragraphs in the **main body** of the essay should contain:

- Key **concept**, with details of biochemical process (as relevant).
- Specific **named example(s)**.
- **Experimental evidence** to support the ideas (even when not specifically asked for in the question). By providing support, you show the examiner that you understand how information was obtained and how strong the evidence is behind the idea—it's a great way of bumping up marks. As you progress through your degree, you will be expected to refer directly to experiments in the primary research literature, so get into the habit of providing experimental evidence early on and it will make it much easier later.
- If possible, illustrate with an **annotated diagram**, e.g. draw out the biochemical pathway (SIMPLY but clearly—you are being marked on scientific content not artistic merit). Remember that diagrams are only of exam value if they are fully annotated (i.e. have descriptive labels) and **don't take longer to draw than it would have taken you to write text describing them**.
- In most universities, it is fine to use colour in diagrams, but do check first. For example, illustrating the complex processes of DNA recombination is made much simpler by using a different colour for each strand of DNA. We have tried to make the diagrams in this book simple and easy to reproduce under exam conditions (though we couldn't use colour because of printing constraints). Most undergraduate textbooks employ graphic artists to make the pictures beautiful; you won't have time to do this in an exam! For example, it is more informative to draw the relevant components of the lac operon as boxes and use good annotation to explain what is happening under different sugar conditions, rather than spending time making your DNA into beautiful double

helices but missing the scientific point. (Obviously if the essay asks about the structure of DNA, then you have to draw the double helix not boxes!).

- Don't repeat the same material in diagrams and text, but do introduce each diagram, e.g. 'the subunit composition of the eukaryotic ribosome is shown'. Remember to use full labels that are clear, legible, and informative.
- Ensure that you leave sufficient space around your diagrams so the reader can easily see what you are illustrating—don't squeeze them into the margins or wrap text around them.
- Comparative tables can also be really helpful to convey factual information rapidly and show the examiner that you can identify key concepts and relate the details to those concepts (e.g. concept: initiation, elongation, and termination in DNA replication; details: the analogous prokaryotic and eukaryotic proteins involved in each step), but make sure you don't rely wholly on such tables, as you will also be marked on the coherency of your discussion.
- Round off each paragraph with how the information you have just presented addresses the question.

Try to include a **conclusion** where you can argue for/against (especially if it's a 'Discuss ...' type essay). You can throw in the odd quirky example here if it didn't fit well into the rest of the essay, but make sure it's relevant. If there are controversies in the field, you can mention them here. Don't waste time repeating things you have already mentioned. You could even highlight what further knowledge is required to fully understand the process (but make sure it's a real gap in knowledge, not simply that you didn't know it!).

Good luck in your exams and do remember that biochemistry is a subject to enjoy—it's not just about passing tests!

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Contents

1 Molecules

1.1 BONDS

Living organisms are made of up of organic molecules consisting mainly, though not exclusively, of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulphur (S). These are held together by bonds which vary in strength and length.

Covalent bonds

- **Covalent bonds** form when electrons are shared between atoms within a molecule
- These are usually the most stable type of bond, although some will break spontaneously
- e.g. C–C or C–H
- Can be single, double, or triple bonds, e.g.

$H_3C — CH_3$	$H_2C = CH_2$	$HC \equiv CH$
ethane	ethene (ethylene)	ethyne (acetylene)

i. sigma (σ): single bond, strongest, formed by head-on orbital overlap, symmetrical with respect to rotation around bond axis
ii. pi (π): double bond where two lobes of one atomic orbital of one atom overlap two lobes of the other, weaker than σ, on-rotational

iii. triple bonds formed by one σ- and two π-bonds—stronger than each individual bond

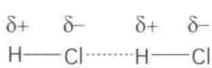
- More energy is required to break double and triple bonds than single bonds
- Electrons can be shared equally (e.g. C–C) or unequally (e.g. O–H) in which case the bond is polarized with the electrons attracted to the electronegative O atom (forming a dipole)
- Many require **enzymes** to make or break them

Ionic bonds

- **Ionic or electrostatic bonds** form between positively and negatively charged ions
- Have some degree of covalent bond nature as atoms close together share electron density
- Intermediate in strength between covalent and hydrogen bonds
- e.g. Na^+Cl^-

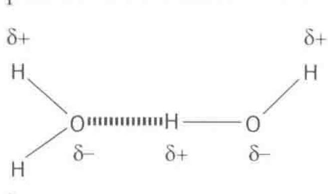
Dipole–dipole interactions

- Dipole = separation of positive and negative charge
- Interaction between permanent dipoles increases **attraction** between molecules
- e.g. HCl



Hydrogen bonds (H-bonds)

- **Hydrogen** or **H-bonds** form between polar molecules
- When H is attached to an electronegative atom such as O or N, the bond becomes polarized
- Bond formed by sharing of non-bonding (lone pair) electrons from one atom with an H covalently attached to an electronegative atom and therefore starved of electrons
- Weaker than ionic bonds but stronger than hydrophobic or van der Waals forces—essentially a strong dipole–dipole interaction
- e.g. stabilize secondary structures of proteins (alpha helices and beta sheets), base pairs in DNA double helix and between water molecules (as shown below)



van der Waals forces

- **van der Waals forces** occur between any atoms
- Transient dipoles formed by electron movement lead to electrostatic **attraction** between atoms/molecules a short distance apart
- Can form between polar or hydrophobic molecules
- Individually weak but additive in large molecules
- At very short distances, van der Waals interactions become strongly repulsive (≤atomic radius)

Hydrophobic effect

- The **hydrophobic effect** will drive the association of hydrophobic molecules in a polar, aqueous environment to exclude water and maximize entropy
- e.g. fatty acids in centre of lipid bilayer or fat droplet
- Individually weak but additive in large molecules

Comparison of bond types

For comparison of properties of important bond types see Table 1.1.

Bond	*Approx. strength (kJ/mol at 25°C)*	*Length (internuclear separation distance) (Å)*	*Where found*	*Example*
Covalent	200–1000	0.7–2.7, e.g. 1.4 for C–C in graphite	intermolecular	peptide bond
Ionic or electrostatic	~40	2.8	inter- and intramolecular	salt bridges
Dipole–dipole	4–20		inter- and intramolecular	
Hydrogen	10–30	2.7–3.1	inter- and intramolecular	between polar side chains of amino acids
van der Waals	4	3–4	inter- and intramolecular	between tightly packed atoms in centre of protein molecule
Hydrophobic effect	<1 per CH_3	3–5	inter- and intramolecular	fatty acids in lipid droplet or membrane

Table 1.1 Comparison of bond types

Note: strength is approximate and varies according to molecules involved.

Check your understanding

Describe the different bond types occuring in organic molecules. (*Hint: can you give an example of each type?*)

1.2 PROTEINS

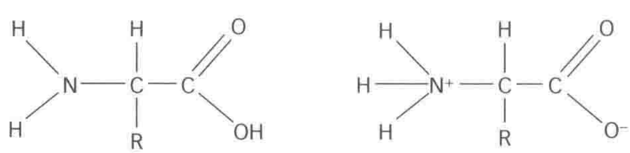
Proteins are essential to all living organisms as they catalyse the majority of enzymatic reactions in the cell and also play an essential structural role. Proteins are polymers of amino acids also referred to as polypeptide chains. The function of a protein is intimately linked to its structure.

Key functions of proteins

- Structural, e.g.
    i. collagen, which forms long fibres
    ii. actin, which forms long filaments made up of short monomers
- Enzymes, e.g. lysozyme
- Carriers, e.g. haemoglobin
- Transmembrane, e.g. ion channels
- Signalling, e.g. insulin

Amino acids

- Fundamental building block of **proteins**
- General structure of an **amino acid** (shown in non-ionized form below and as **zwitterion**)



- Amino acids are **chiral** about the central carbon atom next to the COOH (α-carbon)
- Natural amino acids are the L form (laevorotatory)
- Twenty naturally occurring in proteins that differ in the R side chain (Table 1.2)
- Side chains confer one or more specific characteristics on the amino acid, e.g. tyrosine has an aromatic side chain that possesses an –OH group which can be phosphorylated
- Amino acids form a zwitterion at neutral pH (i.e. in the cytosol) with a positive charge on the amine group and a negative charge on the carboxyl group
- They act as buffers (see Figure 1.1 for titration curve)
- Excess dietary amino acids are broken down:
    i. amino portion is used to form urea in mammals
    ii. carbon skeletons are recycled for the formation of glucose via **gluconeogenesis** (**glucogenic**), or of **ketone bodies** (**ketogenic**)

➔ *see 5.8 Amino acid breakdown and synthesis (p. 156) for metabolism of amino acids*