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AS and A LEVEL

Delivery Guide

H020/H420

BIOLOGY A

Theme:

Nucleotides and Nucleic Acids 2.1.3

March 2015

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Oxford Cambridge and RSA

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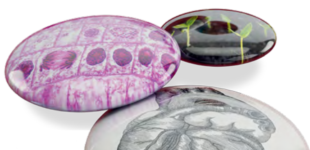


Introduction

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

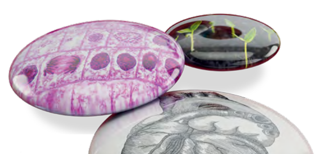
If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resourcesfeedback@ocr.org.uk.

KEY

Click to view associated resources within this document.

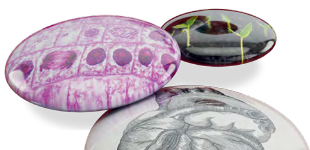
Click here — Click to view external resources

AS Level only — AS Level content only



Curriculum Content

2.1.3 Nucleotides and nucleic acids	
(a) the structure of a nucleotide as the monomer from which nucleic acids are made	To include the differences between RNA and DNA nucleotides, the identification of the purines and pyrimidines and the type of pentose sugar. An opportunity to use computer modelling to investigate nucleic acid structure. **PAG10**
(b) the synthesis and breakdown of polynucleotides by the formation and breakage of phosphodiester bonds	
(c) the structure of ADP and ATP as phosphorylated nucleotides	Comprising a pentose sugar (ribose), a nitrogenous base (adenine) and inorganic phosphates.
(d) **(i)** the structure of DNA (deoxyribonucleic acid) **(ii)** practical investigations into the purification of DNA by precipitation	To include how hydrogen bonding between complementary base pairs (A to T, G to C) on two antiparallel DNA polynucleotides leads to the formation of a DNA molecule, and how the twisting of DNA produces its 'double-helix' shape. **PAG9** HSW3, HSW4

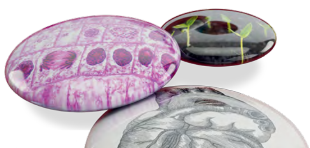


(e) semi-conservative DNA replication	To include the roles of the enzymes helicase and DNA polymerase, the importance of replication in conserving genetic information with accuracy and the occurrence of random, spontaneous mutations. HSW8
(f) the nature of the genetic code	To include the triplet, non-overlapping, degenerate and universal nature of the code and how a gene determines the sequence of amino acids in a polypeptide (the primary structure of a protein).
(g) transcription and translation of genes resulting in the synthesis of polypeptides.	To include, the roles of RNA polymerase, messenger (m)RNA, transfer (t)RNA, ribosomal (r)RNA. HSW8

2.1.3(a) – (d) build up to an understanding of the double helix structure of DNA. Students need to gain confident familiarity with the different parts and bonds of the DNA molecule in order to cope with comprehending the replication (e) and protein synthesis (f–g) topics that follow, as well as later sections of the syllabus (see conceptual links below) that build on this knowledge.

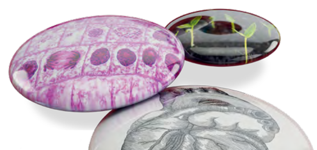
While a grasp of the significance of the linear coding nature of the base-pair sequence supported by the sugar-phosphate backbones is the first goal, it is important that students are trained to be precise in using the biochemical vocabulary to describe the DNA molecule (see student misconceptions below).

Use of videos, 3D animations and models should be backed up with student labelling of 2D diagrams and written tasks which encourage the correct use and spelling of the key terms. Where internet-based learning resources go into more detail than text books, the syllabus and OCR legacy past questions and mark schemes provide a guide to the level of detail and accuracy students should attain.



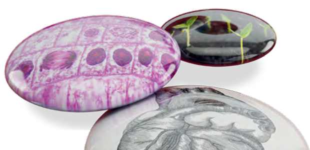
Curriculum Content

Activities	Resources
DNA Structure Video Animations (Cold Spring Harbor Laboratory DNA Learning Center) http://www.dnalc.org/resources/3d/09-5-dna-has-4-units.html http://www.dnalc.org/resources/3d/07-how-dna-is-packaged-basic.html These short video clips show the basic structure of the DNA molecule and relate the molecular level to the whole chromatin and chromosome (cell) level, which is an important link for students to make.	
DNA Your Onions (National Centre for Biotechnology Education, Reading University) 2.1.3(d) http://www.ncbe.reading.ac.uk/NCBE/PROTOCOLS/PRACBIOTECH/PDF/onion.pdf This worksheet gives a tried and tested protocol for extracting DNA from onions in a school laboratory. Ideally students will carry out the whole procedure themselves but if time is short the onion filtrate can be pre-prepared and students can just perform the final extraction step.	
DNA Replication Video Animation (Biology/Medicine Animations HD) https://www.youtube.com/watch?v=27TxKoFU2Nw High-quality graphics and an easy to follow soundtrack makes this a useful teaching tool. The level of detail is greater than that required by the syllabus so students should be guided to concentrate on absorbing the basics specified on the syllabus rather than the extra details. This animation and other high-quality video clips from this company are available through YouTube. If your school network does not allow access to YouTube there are instructions at the following link for downloading and incorporating videos into PowerPoints. http://doctorprodigious.wordpress.com/hd-animations/#13gmb This houses a complete list of other molecular biology and biology animations from this source.	



Curriculum Content

Activities	Resources
Transcribe and Translate a Gene (Genetic Science Learning Center, University of Utah) http://learn.genetics.utah.edu/content/molecules/transcribe/ Students type in the matching mRNA sequence and then act as tRNAs by matching mRNA codons with the correct amino acids, using a table of the genetic code. Other learning resources for this module can be accessed via this link: http://learn.genetics.utah.edu/content/molecules/	Click here
The Central Dogma song (Howard Hughes Medical Institute Biointeractive) http://www.hhmi.org/biointeractive/central-dogma-song This might provide light relief and inspire students to create their own song or rap to learn the names of the bases, base-pairing rules and flow of information in protein synthesis.	
Key Terms Worksheet This is simply a sheet listing words that students should be able to define and relate to each other when they have studied this module. It can be used in various ways: • Use at the start of the topic for students to assess their initial familiarity or to tick off as work progresses • colour-code or join groups of words judged by students to belong together • categorise the words in a table or mind diagram as molecules, processes, monomers, polymers, organelles, enzymes, bonds, etc. • enclose words related to the same topic or level of organisation within lines of different colours to make a Venn diagram • cut out the words and re-arrange them into groups according to different criteria, eg order of size of molecules or cell structures, order of use of each component in protein synthesis • define the words • use the words to play hangman or a 'pictionary' style game • match the words to the syllabus outcomes (a-g) • use at end of topic to write a summary of topic 2.1.3 using each word in the correct context at least once.	Learner Resource 1



Thinking Conceptually

Approaches to teaching the content

As a fundamental underpinning of Biology, DNA structure needs to be taught rigorously and the significance of its three functions made clear:

- Coding biologically useful information via transcription and therefore acting as a blueprint for building cells and bodies
- ensuring continuity within a multicellular organism and between generations through semi-conservative replication
- allowing evolution to occur by generating variation through mutation.

Common misconceptions or difficulties students may have

There are a number of common misconceptions that surface in student exam answers. These include:

- Misunderstanding that the double helix means that a DNA **molecule** is composed of two strands. It is common for students to refer to the whole double-stranded molecule as a 'strand of DNA'.
- Using the words **base** and **nucleotide** interchangeably and inappropriately, for example, saying that new bases come in and pair up with DNA during replication.
- Confusion between transcription and translation, and between replication and transcription.
- Misuse of the verb 'transcribe', for example, saying the mRNA transcribes the DNA rather than that the DNA is transcribed (passive) into mRNA.
- Failing to discriminate between DNA, mRNA and protein sequences.
- Misunderstanding that the word mutation refers to a change in the DNA, not in mRNA and protein sequences.
- Failing to adequately discriminate between the gene (DNA) and the gene product (protein) in contextual questions.

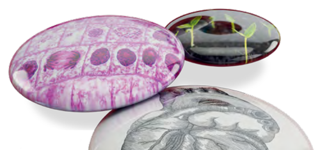
Conceptual links to other areas of the specification – useful ways to approach this topic to set students up for topics later in the course

A thorough knowledge of this section is a prerequisite for study of cellular control (6.1.1), patterns of inheritance (6.1.2), manipulating genomes (6.1.3) and cloning (6.2.1 a-d). It is also important to relate molecular changes at the DNA level to classification and evolution (4.2.2) as well as to biodiversity (4.2.1a).

Knowledge of DNA structure and function should inform work on the cell cycle (2.1.6) also, particularly the relationship between the DNA double helix and whole chromosome structure, and the occurrence of DNA replication at S of interphase in the cell cycle. The relationship of the two daughter DNA molecules to sister chromatids should also be stressed to make the link between the molecular level and whole cell functioning.

In section 2.1.1(i) students tend to concentrate on the ribosome and Golgi body, overlooking the role of the nucleus, so the role of DNA and the enzymes involved in transcription should be stressed.

For all work on applications of genetics, it is vitally important that students retain a working knowledge of the structure of the DNA molecule and of the link between the base sequences in DNA and mRNA and the amino acid sequence in proteins.



Thinking Conceptually

<table>
<tr><th>Activities</th><th>Resources</th></tr>
<tr><td>

Building DNA - advanced version!
An activity designed to consolidate student knowledge of the structure of DNA. There is now a plethora of different ways of producing DNA models (see the two links below), but students are expected to show increasing understanding of the way in which components fit together. Consider spending some time with the nucleotide 'molecule' containing Adenine to show how this is a precursor to ADP and ATP (2.1.2c).

The activity is best completed in small groups of 3-4 to enable students to construct a double helix using criteria shown in Learner Resource 2.

- Using chosen materials eg molecular modelling kits or paper, build at least four nucleotides per student, representing **A**, **T**, **C** and **G**. They must choose a suitable colour key for different components and maintain this key throughout the activity.
- Once the nucleotides are made, join these to form a single-stranded polynucleotide. (The strand should contain at least 10 nucleotides which can be joined in random sequence to provide some interest in later activities involving translation and transcription).
- Using this strand as a template, single nucleotides can now be added (refer to Learner Resource 2 for criteria). These are then joined to form the second strand once the 'complementary base-pairing rule' has been observed. More nucleotides may need to be made at this stage dependent on the sequence chosen.
- Finally twist the molecule - how many nucleotides per twist are found in the double helix?

Save this molecule for use in further activities.

Worksheets for different DNA modelling ideas
http://www.gov.mb.ca/conservation/sustain/dnadone.pdf

This website is a Manitoba government website but has a conservation section with a good worksheet example for model DNA.

http://www.biologycorner.com/worksheets/dna_model_nucleotides_key.html

Another example for completing DNA models.

</td><td>Learner Resource 2</td></tr>
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CONTEXTS

The first four resources (below) place understanding DNA structure and function within its historical context. Some students engage more positively with this human interest angle than with the structural formulae and technical vocabulary of the subject. The history of science context also demonstrates that the knowledge in textbooks is hard-won and took years to elucidate. A third advantage of this approach is that it shows how the scientific community operates and the degree of competition and collaboration between researchers.

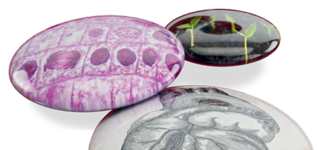
Many of the applied contexts within which knowledge of DNA is important arise later in the course, though with a linear scheme of assessment there is no reason why key topics of interest should not be cherry-picked from later modules and introduced early to give students an idea of how DNA structure is relevant to modern life. Topics such as DNA fingerprinting for forensics or wildlife forensics, testing for genetic diseases, sequencing a person's DNA and applications of genetic modification could be taught to reinforce knowledge of DNA structure or the link between genes and proteins. A link to online activities relating to four applications is given (below).

Thinking Contextually

Activities	Resources
Life Story Film, Checklist of Scientists and DNA Worksheet 'Life Story', also re-named 'The Race for the Double Helix': (BBC Horizon, 1987). This film is available on the educational video-sharing service Clickview for those schools that subscribe, and copies exist online on various video-sharing sites. The drama is an hour long but provides a fascinating context for understanding the structure of DNA and the excitement generated by this discovery. Learner resource 3, the 'Life Story Checklist of Scientists' sheet, lists the main characters to help students follow the story. Follow on questions on Learner resource 4, the 'Discovering the Structure of DNA' worksheet (year 12 version), focus on the structure of DNA.	Learner Resource 3 Learner Resource 4
Shorter film on discovery of DNA structure Great Discoveries in Science: The Double Helix (Howard Hughes Medical Institute): http://www.hhmi.org/biointeractive/great-discoveries-science-double-helix This is a 17 minute video on the discovery of the structure of DNA if the BBC Life Story version is considered too long.	
Interactive Timeline on history of DNA research DNA Interactive Timeline (Cold Spring Harbor Laboratory's DNA Interactive website) http://www.dnai.org/timeline/index.html This covers key breakthroughs in the study of genetics and inheritance in each decade of the 20th century. Information about personalities and their research will familiarise students with key facts like Chargaff's ratios of bases and the structure of the DNA molecule.	

Thinking Contextually

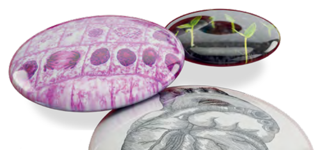
Activities	Resources
Chargaff's Ratios Before completing this activity, students should have prior knowledge of the history of DNA and some of the key individuals involved in its discovery. Having constructed a model DNA molecule in the activity 'Building DNA - advanced version!', students now have the opportunity to look at the evidence that was available to Watson and Crick in their quest to discover the secrets of the DNA molecule. Using some of the data from Chargaff's research, students are encouraged to complete simple mathematical calculations involving ratios (*M0.3*) and formulate their own conclusions.	Learner Resource 5
Problem-solving approach to key aspects of DNA function DNA Interactive Code (Cold Spring Harbor Laboratory's DNA Interactive website) http://www.dnai.org/a/index.html Problems to be solved include Finding the Structure (basic DNA molecule structure), Copying the Code (DNA replication), Reading the Code (protein synthesis) and Controlling the Code (gene regulation).	
Applications (Cold Spring Harbor Laboratory's DNA Interactive website) http://www.dnai.org/d/index.html Applications covered are DNA profiling, identifying the Russian royal family by DNA evidence, molecular genetics in medicine and the family tree of the human species.	



Learner resource 1 Nucleotide and Nucleic acids key terms

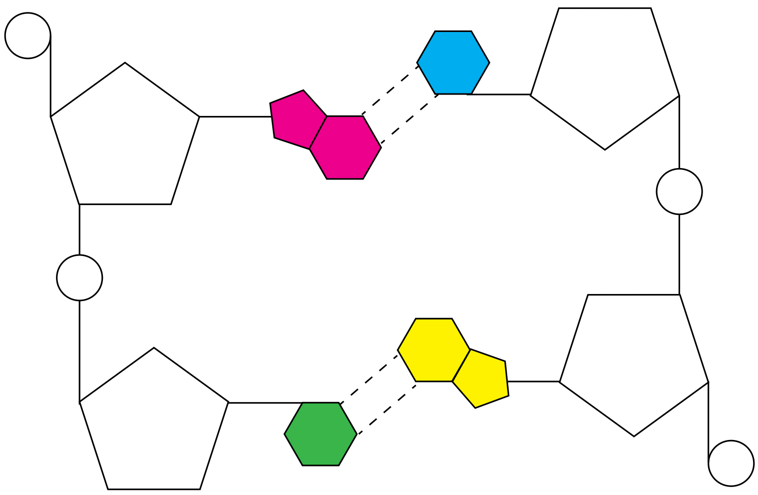
See page 8

TRANSCRIPTION	GENE	ATP	POLYPEPTIDE	BASE-PAIRING
MUTATION	tRNA	AMINO ACID SEQUENCE	DNA	DOUBLE HELIX
CYTOSINE	GUANINE	TRANSLATION	DNA POLYMERASE	THYMINE
DEOXYRIBOSE	mRNA	COMPLEMENTARY	PURINE	PYRIMIDINE
RNA POLYMERASE	PHOSPHODIESTER BOND	CODON	NUCLEOTIDE SEQUENCE	ADP
RIBOSE	RIBOSOME	GENETIC CODE	ADENINE	SUGAR-PHOSPHATE BACKBONE



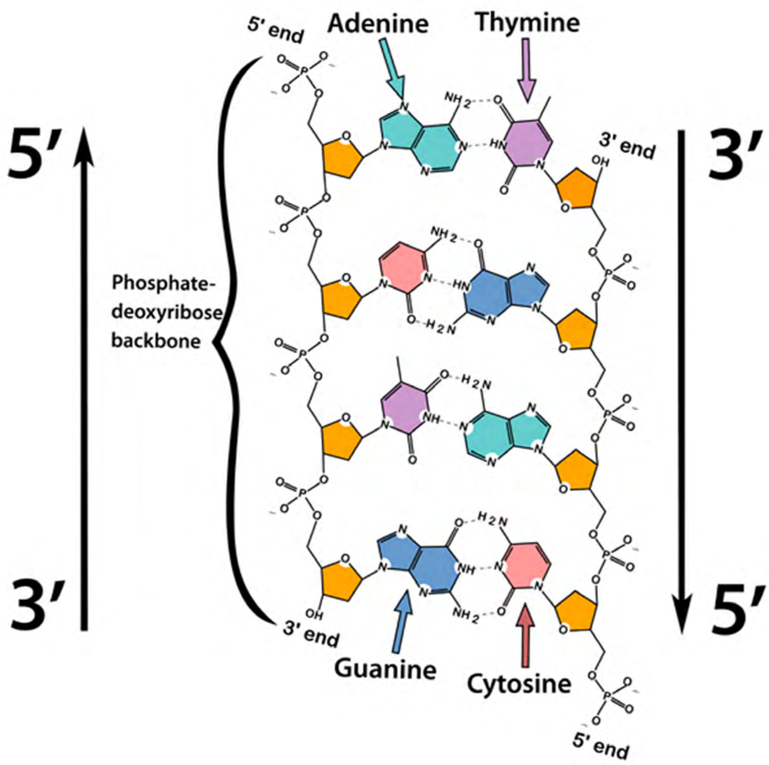
Learner resource 2 Advanced DNA models

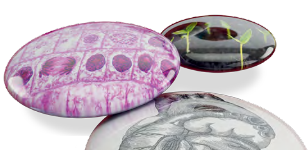
See page 10



Remember for an advanced model:

- Your model must show the ribose sugar, the phosphate group and a nitrogenous base in the nucleotide
- Your model must show representative size/shape differences for purines and pyrimidines
- Your model must have two antiparallel strands
- Your model must be held by an appropriate number of 'bonds' between complementary base pairs
- Your model must be able to twist into a double helix (check how many nucleotides per twist).

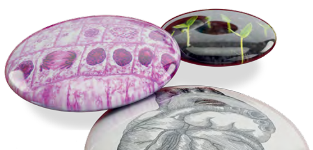




Learner resource 3 Life Story Checklist of Scientists

See page 12

Name	Most famous discoveries	Nobel prize winner?
Rosalind Franklin		
James Watson		
Francis Crick		
Maurice Wilkins		
John T.Randall		
Sir Lawrence Bragg		
Sir William Henry Bragg		
Max Perutz		
Linus Pauling		
Peter Pauling		
John Kendrew		
Raymond Gosling		



Learner resource 4 Discovering the structure of DNA

See page 12

1. What are the three molecular components of DNA?

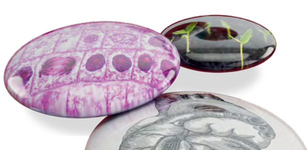
2. What technique revealed important information about the positioning of these molecular components in DNA?

3. What was unique about Watson and Crick's approach to working out how the components of DNA fit together?

4. What is significant about the way the two strands of a DNA molecule are complementary copies of each other?

5. Why do you think the discovery of the structure of DNA generated such excitement?

6. Has the potential of DNA as 'the secret of life' been fulfilled? How has knowledge of DNA been applied in medicine, agriculture and industry?



Learner resource 5 Chargaff's Ratios

Background Information

See page 13

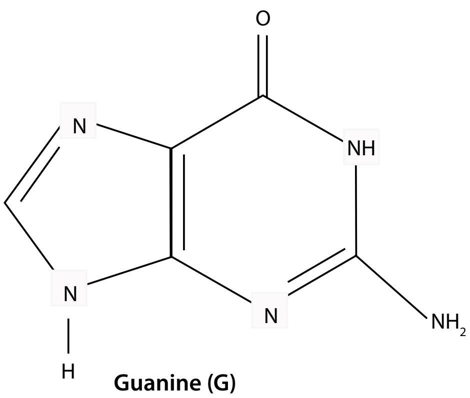
Despite the fact that DNA had been discovered in the 19th century early researchers struggled to determine the structure of the molecule. It was already known that DNA was comprised of repeated units called nucleotides and that each nucleotide contained a part called a nitrogenous base, but how they were put together eluded them.

Could DNA be the genetic material scientists had been looking for? If, as was commonly believed, these nitrogenous bases occurred in all living things in the same repeated pattern, eg TAGC/TAGC then DNA could not be the genetic material. Chargaff's research revealed the percentage of each base (A, T, G, and C) found in an organism's DNA which aided Watson and Crick in their quest to determine its structure and prove it to be the 'molecule of life'.

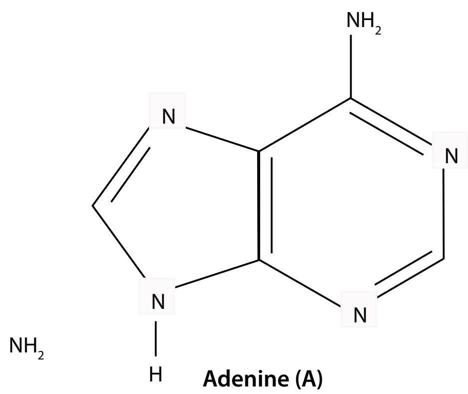
Organism	% Nitrogenous base content			
	A	T	G	C
M. tuberculosis **(bacterium)**	15.1	14.6	34.9	35.4
yeast	31.3	32.9	18.7	17.1
wheat (not part of original data)	27.3	27.1	22.7	22.8
sea urchin	32.8	32.1	17.7	17.3
herring	27.8	27.5	22.2	22.6
rat	28.6	28.4	21.4	21.5
human	30.9	29.4	19.9	19.8

Table 1 shows the percentage content of each nitrogenous base found in the DNA of different organisms

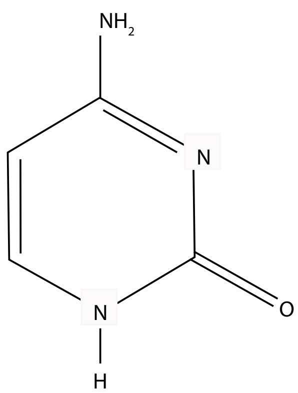
The four nitrogenous bases found in DNA can be classified into two groups, purines and pyrimidines. These are shown in the diagrams below: adenine and guanine are purines; cytosine and thymine are pyrimidines.



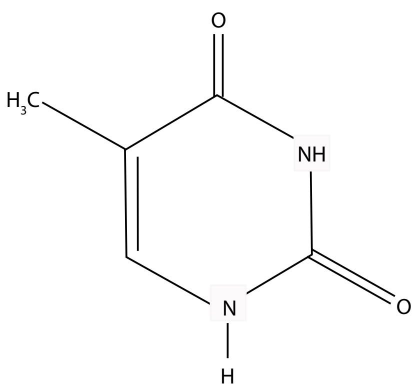
Guanine (G)



Adenine (A)

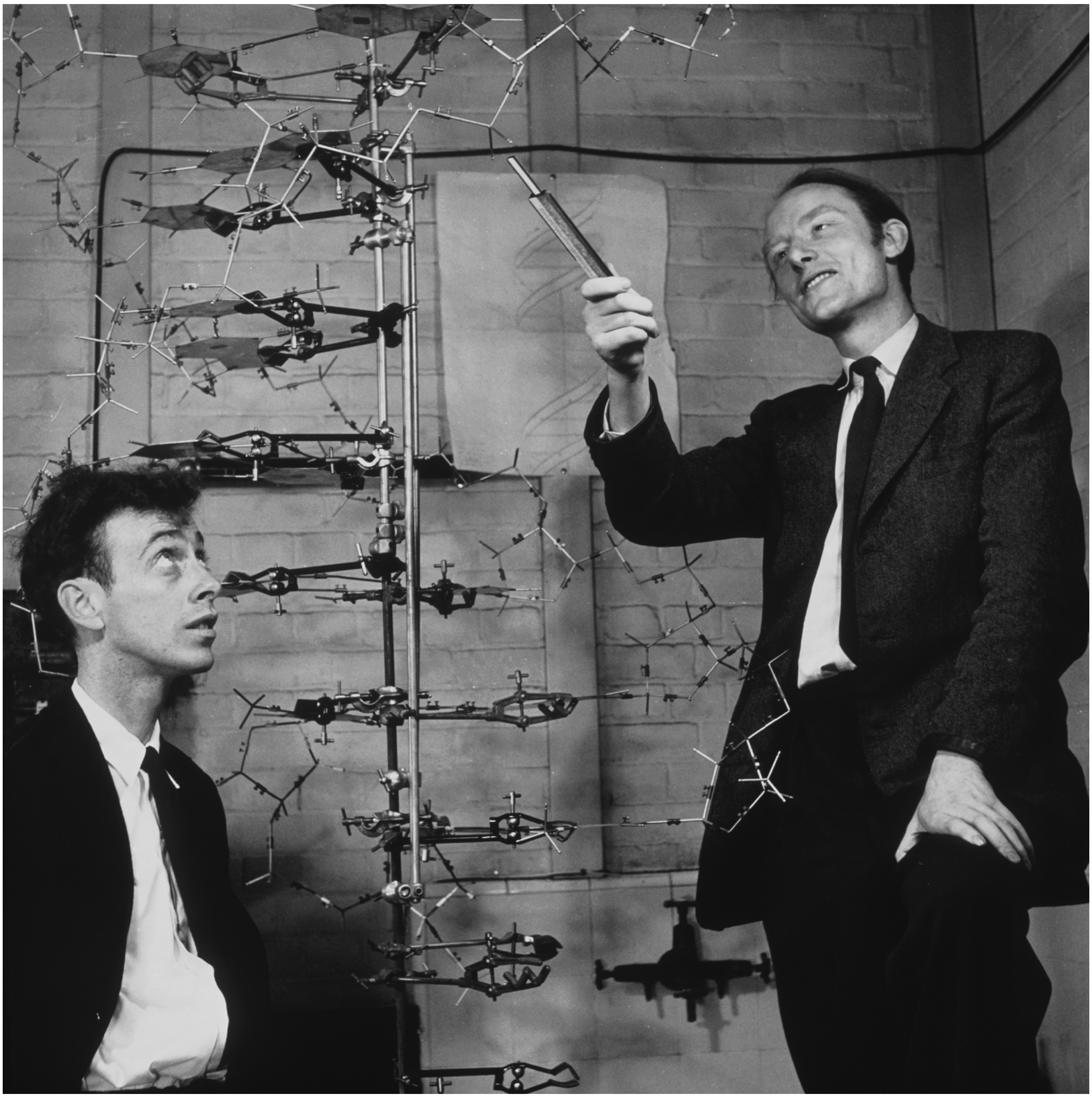


Cytosine (C)



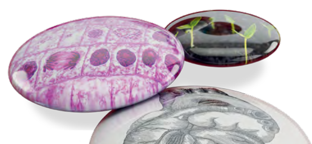
Thymine (T)

1. Analyse the data in **Table 1** noting any patterns you see.
2. Using **Table 1**, calculate the ratios of purines to pyrimidines for five different organisms.
   Present your calculations in an appropriate table.
3. What does the data and your calculations reveal about DNA in different species?
4. Explain how this research enabled Watson and Crick to suggest a structure for DNA (shown below).



The discoverers of the structure of DNA. James Watson (b. 1928) at left and Francis Crick (1916-2004), with their model of part of a DNA molecule in 1953. Crick & Watson met at the Cavendish Laboratory, Cambridge, in 1951. Their work on the structure of DNA was performed with a knowledge of Chargaff's ratios of the bases in DNA and some access to the X-ray crystallography data of Maurice Wilkins and Rosalind Franklin at King's College London. Combining all of this work led to the deduction that DNA exists as a double helix. Crick, Watson and Wilkins shared the 1962 Nobel Prize for Physiology or Medicine, Franklin having died of cancer in 1958.

Photographed in the Cavendish Laboratory, University of Cambridge, UK, in May 1953.



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