Chapter 1: Genetics

Pages 1–38

Teacher notes

Introducing the chapter:

This chapter looks at the structure of the nucleic acids, DNA and RNA, and their role in the processes of DNA replication, cell division, and protein synthesis. The structure of DNA, genes and chromosomes are compared. The consequences of mutations and other factors in the environment which provide functional variety to the genotypes and phenotypes of organisms. Monohybrid crosses and pedigree charts are used to determine the inheritance of traits, including co-dominant and sex-linked traits. The human needs and demands of manipulating DNA is introduced in:

• genetic screening and testing of diseases such as cystic fibrosis

• gene cloning in the production of human proteins such as insulin

• gene transfer of healthy human genes such as the cystic fibrosis gene

• genetically engineered in the production of genetically modified and transgenic crops.

Teacher notes

1.1 Scientists review the research of other scientists

Pages 2–3

Introducing the topic:

This topic explains how our scientific understanding of genes and DNA is constantly being reviewed, challenged and refined. Scientists often collaborate and share their research, and sometimes competing to make scientific discoveries. This unit covers the work of scientists Gregor Mendel, the father of genetics, Watson and Cricks’ research on the double helix structure of DNA as well as other contributing scientists, including Rosalind Franklin.

Teaching tip:

It is useful to use the analogy of detective work. The five clues given had to be put together to create a molecule that we cannot see. Linus Pauling first proposed a model that used three helical structures. Another model suggested that the bases were on the outside of the molecule with a central backbone.

Additional activity: alternative model to the double helix structure

Develop an alternative model to the double helix structure. Can the students argue their case effectively?

This is a replica of how scientists present their research today. Once they have done the research, they must write a paper and present it to a reputable journal to be published. Once it is published, they must be prepared to present their findings at meetings around the world.

Additional activity: timeline

Create atime line of sequence of events in the search for DNA including the work of other scientists such as Miescher, Morgan, Griffith, Levene, Avery, and Chargaff.

Going further:

Review the work of other scientists that have contributed to our understanding of genetics.

Look at x-ray crystallography images of Rosalind Franklin and show how these gave Watson and Crick the additional evidence they needed to publish their paper on the double helix structure of DNA.

Teacher notes

1.2 DNA consists of a sugar–phosphate backbone and four complementary nitrogen bases

Pages 4–5

Introducing the topic:

The double helix structure of DNA and importance of DNA to be able to self-replicate and carry information – this unit covers the structure of the four nucleotide building blocks of DNA and how these join to form polynucleotides. Two polynucleotides join by complementary base pairing between nitrogen bases by weak hydrogen bonds to form DNA.

Teaching tip:

When drawing the nucleotide structure, it is important to note where the phosphate group and nitrogen base form a bond with the five-carbon sugar. It is useful to think of the five sides of the sugar as a house, with the phosphate group bonded with one corner of the roof, and the nitrogen base with the other corner of the roof.

Teaching tip:

The matching of nitrogen bases is often best practised by writing the complementary sequences to given strands.

Additional activity: writing complementary sequences to DNA strands

Get students to write complementary sequences to DNA strands. For example:

ACT GGA CTT CCT GGA (answer: TGA CCT GAA GGA CCT)

GAC GCC TTA AAA CGC (answer: CTG CGG AAT TTT GCG)

GTT CCC GAT GAT CTA (answer: CAA GGG CTA CTA GAT)

The grouping of these nucleotides into sets of three is deliberate as this is how the bases are often read when making a protein.

Additional activity: Pictionary game

Use the Pictionary game to draw terms used in this unit: Students work in teams. One student from the first team is given the word card and has to draw a picture that represents the word. The team has one minute to guess the word. One point is awarded for each word guessed within the time limit.

Terms given could include antiparallel, deoxyribose sugar, nitrogen base, sugar-phosphate backbone, complementary bases, double helix etc.

Going further:

Look at the strong covalent bonding between the phosphate group of one nucleotide and the five-carbon sugar on the next nucleotide. The backbone of this sugar–phosphate polymer chain is very strong as a result of these bonds.

Label the carbons on the deoxyribose sugar 1-5 to show the antiparallel nature of DNA.

Brainstorm ideas as to why the hydrogen bonds are weak between the bases yet strong covalent bonds join the sugar-phosphate backbone. Ideas could include the need for DNA to unwind and separate in sections during protein synthesis and DNA replication.

Teacher notes

1.3 Chromosomes are DNA molecules carrying genetic information in the form of genes

(Pages 6–9)

Introducing the topic:

This topic covers the relationship between DNA, genes and proteins. Human karyotypes are shown to show homologous autosomes and sex chromosomes. The two nucleic acids DNA and RNA are compared and the process of protein synthesis is introduced.

Teaching tip:

The relationship between DNA, genes and proteins is important in both senior chemistry and senior biology. A cell will only make protein when it is not replicating. The double helix structure of a DNA molecule partially unwinds and an RNA molecule is made.

Teaching tip:

When writing DNA sequences write the nitrogen bases as triplets (three bases followed by a space) as this will help students grasp the idea of triplets and codons when completing amino acid sequences for protein synthesis and later on in the mutations unit.

Teaching tip:

As DNA cannot leave the nucleus, RNA is needed to carry the genetic instructions to the rest of the cell. For this reason, an RNA copy is made, like a photocopy of a single page of a blueprint, which then leaves the nucleus to pass on the message.

Additional activity: comparing and contrasting with Venn diagrams

Use Venn diagrams to compare and contrast:

• transcription and translation

• DNA and RNA.

Additional activity: writing RNA sequences

Practise writing RNA sequences from DNA sequences.

Additional activity: representation of a DNA molecule

The use of four different coloured paper clips to represent the four nitrogen bases gives the best representation of a DNA molecule. The coloured card can be cut into strips to represent the sugar–phosphate backbone. One strand of DNA can be made up by hooking the paper clips around the card so that they sit at a right angle. The second strip of card can then be laid next to the first strand and the paper clips matched with the first set; for example, green paper clips (G) match with yellow paper clips (C), and blue paper clips (T) match with red paper clips (A).

Students could make a copy of an RNA molecule from their DNA molecule. To do this, the students can open their double-stranded DNA molecule and make a complementary short strand of RNA using a paper clip with another colour (e.g. black) for the uracil (U) nitrogen base. When the RNA molecule is finished, the DNA re-joins its complementary strand, leaving the RNA alone to leave the nucleus.

Additional activity: translating a section of DNA

Write a section of DNA on the board (e.g. CTC TTA GAG CTT ACT). Students must translate this into an mRNA sequence and then an amino acid sequence using an amino acid table. Students can make up the protein chain using lollies to represent the amino acids (e.g. Minties for Glu, Fantails for Asn, and sherbets for Leu). The lollies can be stapled or stuck together with sticky tape. This will make a chain of Minties–Fantails–sherbet–Minties–STOP. Once students have a correct chain, they can eat the lollies.

Going further:

Use codon charts to translate RNA sequences into amino acid sequences.

Discuss ideas involving differences in the nitrogen base sequence of different alleles and how this alters a sequence of amino acids in a protein.

Teacher notes

1.4 Mitosis forms new somatic cells

(Pages 10–11)

Introducing the topic:

Mitosis is the process of cell division in somatic cells whereby DNA replicates, chromosomes separate, and the cell divides by cytokinesis to produce two identical, diploid daughter cells. Mitosis is important for growth, repair and replacement of somatic cells and occurs in a series of stages from interphase to cytokinesis.

Teaching tip:

It is important for students to fully understand the difference between haploid and diploid chromosomes.

Teaching tip:

Students struggle with differences between mitosis and meiosis. A simple, yet often effective, phrase to use is ‘**my toes** don’t have sex’. This refers to the fact that **mito**sis is not involved in the production of sex cells.

Additional activity: memory game

Memory game could be used or made to match stages with processes occurring.

Additional activity: ‘handy model’ of mitosis

Kinaesthetic learners or students struggling to remember the processes occurring may benefit from creating a ‘handy model’ of mitosis. There are many on the internet to use or students could create their own.

For example. One hand as a fist represents DNA which replicates, shown by two fists together. Chromosomes lined up could be finger tips as pairs lined up together, then spindles (fingers) pull apart and chromosomes (fingertips) separate etc.

Going further:

Students could research differences in mitosis of plant cells compared to animal cells – for example, how does a plant cell wall affect the process of mitosis?

Research cancerous cells or how tumours form. Link ideas to stages of mitosis – for example, most cells are in a stage of interphase where they are not dividing.

What is it about cancerous cells that enables them to divide much more rapidly that a non-cancerous cell? What prevents cancerous cells from entering apoptosis?

Teacher notes

1.5 Meiosis forms gamete cells

(Pages 12–13)

Introducing the topic:

Meiosis is the process of cell division in the cells that produce gametes. The DNA replicates, chromosomes separate and divide by cytokinesis to form two cells which then divide once more by cytokinesis to produce four, haploid daughter cells. Meiosis is important for the production of gametes which upon fertilisation produce diploid zygotes with a full set of chromosomes.

Teaching tip:

The difference between meiosis and mitosis is often difficult for students to distinguish. One of the most common difficulties is the similarity of the names themselves. A simple, yet often effective, phrase to use is ‘toes don’t have sex’. This refers to the fact that mitosis is not involved in the production of sex cells.

Teaching tip:

It is essential that students grasp the importance of haploid gametes to ensure a zygote has a full diploid set of chromosomes upon fertilisation. For example, haploid egg + haploid sperm 🡪 diploid zygote.

Additional activity: mitosis and meiosis poster

It is useful for students to make a poster of the two processes, with mitosis being on one side of the poster and meiosis on the other.

Additional activity: meiosis memory game

Memory game for meiosis: this could include terms such as haploid, diploid, fertilisation, zygote, gamete, egg, sperm, interphase, prophase, metaphase, anaphase, telophase, cytokinesis, and meiosis. Lay all the words and definitions upside down on the desk. Students take it in turns to turn two cards over. If the cards match (word with definition), then the student keeps the cards. If the cards do not match, then they are turned upside down again and it is the next student’s turn.

Going further:

Develop the idea of haploid gametes further. Show how 23 chromosomes (22 autosomes and 1 sex chromosome) are present in a haploid gamete compared to 23 **pairs** of chromosomes (or 46 chromosomes) in a somatic cell.

This could be shown in male gametes (sperm) could either have an X or a Y whereas in female gametes will only have a single X, so upon fertilisation it is the sperm that determines the sex of the zygote offspring.

Teacher notes

1.6 Alleles can produce dominant or recessive traits

Pages 14–15

Introducing the topic:

Alleles are the different versions of a gene on the same location of a chromosome. The unique combination of alleles for an inherited gene is called the genotype of the organism and can be either dominant or recessive. The expression of this genotype is referred to as the phenotype. Phenotypes are influenced by the environment. Punnett squares are used to predict genotypic and phenotypic ratios of a monohybrid cross, showing how a single trait is passed on.

Teaching tip:

When completing Punnett squares. make sure students select suitable letters to represent alleles – for example, C and W are not good letters to select.

Teaching tip:

Ensure students understand that ‘a Punnett square shows the percentage chance of a characteristic in offspring’ means how many offspring in an ideal world will have this characteristic. In the real world, it is the chance of the offspring displaying the characteristic. This is reset for each time a child is born. For example, two parents who are heterozygous for a widow’s peak have a 50% chance of having a child with a widow’s peak. Even if they already have two children with a widow’s peak, they still have a 50% chance of their next child having a widow’s peak.

Additional activity: practising enotypic and phenotypic ratios

Include lots of practice involving determining genotypic and phenotypic ratios from Punnett squares as well as drawing your own.

Going further:

Research polygenic traits such as eye colour and skin colour which involve more than one gene.

Teacher notes

1.7 Alleles for blood group traits co-dominate

Pages 16–17

Introducing the topic:

This topic looks at the inheritance of the co-dominant A and B blood groups over the recessive blood group, O as well as the inheritance of rhesus grouping. Red blood cells can display special molecule markers on their surface. Co-dominant alleles give rise to a new phenotype being produced in heterozygous individuals as both alleles are equally expressed because they are both dominant.

Teaching tip:

Ensure students use appropriate symbols for co-dominant alleles – for example, there are two dominant ‘I’ alleles IA and IB for the A and B blood groups, and one recessive allele i for the O blood grouping.

Teaching tip:

Many students will know their blood type as A+ etc. Use these examples to make it meaningful to students when explaining what this means– for example, for a person to have a particular blood type and rhesus grouping with regards to sugars present on their red blood cells.

Additional activity: monohybrid crosses

Complete monohybrid crosses for other examples of co-dominance. For example, Roan cattle are produced, which express both red and white hairs equally, as red and white are both dominant alleles.

Additional activity: blood groups/rhesus combinations graph

Create a graph from the data in table 1.1 to show the percentage of each of the eight different blood groups/rhesus combinations in Australia.

Going further:

Investigate incomplete dominance where neither allele is dominant over the other. For example: In snap dragons, neither red nor white petal colour is dominant and therefore there are three phenotypes, red, white and pink.

Research why it is important for pregnant woman need to know if they are rhesus positive or negative.

Teacher notes

1.8 Alleles on the sex chromosomes produce sex-linked traits

Pages 18–21

Introducing the topic:

Sex chromosomes determine the sex of an organism. While human females have two X chromosomes, males have an X and a Y chromosome. The inheritance of genes on the sex chromosomes is unique and often results in sex-linked conditions which occur in different ratios, depending on the sex of an individual.

Teaching tip:

Highlight the idea of females having two X chromosomes, and so can be carriers of an X-linked disorder. Most diseases discussed in this unit are X-linked, as Y-linked disorders are extremely rare. As females have two X chromosomes, they will need two copies of alleles for an X-linked recessive trait for it to be expressed. X-linked traits are expressed more commonly in males as they have a single X chromosome.

Teaching tip:

The introduction of sex linkage is an ideal opportunity to revise meiosis and how sex is determined. Females can only pass on an X chromosome to their offspring. Males produce four sperm cells through meiosis, two with an X chromosome and two with a Y chromosome. Therefore, it is the father that determines the sex of the child.

Additional activity: investigating sex-linked traits

Investigate sex-linked traits in other organisms, such as tortoiseshell cats.

Going further:

Research how the sex chromosomes of other organisms differ from those of humans.

Research how blood donations are used in the treatment of haemophilia.

Teacher notes

1.9 Inheritance of traits can be shown on pedigrees

Pages 22–25

Introducing the topic:

Pedigrees are used to show the inheritance pattern of a trait in a family over two or more generations. Pedigrees can be analysed and interpreted to show whether a trait is dominant or recessive, autosomal or sex-linked. Pedigrees provide information to show the possibility of offspring inheriting a trait.

Teaching tip:

Students find it useful to have a series of questions to ask when analysing pedigrees. Keys like the one below can be used for simple pedigrees at this level.

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | Does one sex show the trait significantly more (>2 times) than the other? | Yes | Sex linked  Go to 4 |
|  |  | No | Autosomal  Go to 2 |
| 2 | Does every affected child have an affected parent? | Yes | Go to 3 |
|  |  | No | Autosomal recessive |
| 3 | Do both affected parents have unaffected children? | Yes | Autosomal dominant |
|  |  | No | Autosomal recessive |
| 4 | Do all affected males have an affected mother? | Yes | X-linked dominant |
|  |  | No | X-linked recessive |

Please note that this key is for use with basic pedigrees only. Occasionally, a pedigree will not provide enough information for the key to be used.

Teaching tip:

Although the term ‘dwarfism’ is commonly used, many people with achrondoplasia prefer the term ‘short stature’. This trait is characterised by an adult height of 130 cm for men and 125 cm for women. During a baby’s development, cartilage normally develops into bone. In people with achondroplasia, the cartilage cells develop into bone more slowly than normal. This is most evident in the arm and leg bones. The torso of affected people is relatively normal in length.

Additional activity: analysing pedigrees

Students could create their own more advanced key by making a series of questions to ask when analysing pedigrees.

Additional activity: creating pedigree charts

Students could create their own pedigree charts from information provided to practise using the correct symbols.

Going further:

Create a concepts map comparing the four patterns of inheritance. This could include how they each is inherited, genotypic and phenotypic ratios from Punnett squares, examples, and pedigree charts to show typical inheritance patterns.

Teacher notes

1.10 Mutations are changes in the DNA sequence

(Pages 26–28)

Introducing the topic:

Mutations are permanent changes in the nucleotide sequence of DNA. The can be caused by errors during DNA replication or mutagens within the environment. Genetic mutations occur within the nucleotide sequence of a gene while chromosomal mutations are generally caused by non-disjunction during meiosis and affect an entire chromosome.

Teaching tip:

Mutations are not always bad for an organism. It has been suggested that a single mutation thousands of years ago prevented the production of brown pigment in eyes. As a result, humans developed blue eyes. The mutation gave humans a new allele. Some mutations, however, are deadly and our body works hard to overcome them.

Teaching tip:

When discussing mutations, it is important to remind students that the DNA code is read in groups of three. This is then transferred to the codons of messenger RNA. Any interruption of this code can have large consequences.

Teaching tip:

Use the idea of a point mutation being like changing a sentence, and then chromosome mutations are like adding, duplicating or deleting a whole chapter of a book. In some books it might not have an impact on the enjoyment of the reader; however, other books may become unreadable.

The difference between the types of mutations can be demonstrated with a simple sentence, as shown below: THE CAT RAN FAR AND SAT. A substitution would therefore make the code: THE CAR RAN FAR AND SAT. This small change may make a difference, or it may not.

A deletion, however, can make a large difference: THE CAR ANF ARA NDS AT. The code is no longer recognisable. This is why an insertion and deletion are called frame shift mutations.

Additional activity: codons and amino acid sequences

Write a nucleotide sequence as triplet for students to transcribe into codons and then translate into amino acid sequence. Then give them different scenarios where they delete/substitute/insert different nitrogen bases and rewrite the codons and amino acids to see the damaging affect they can have. Make sure you include one substitution which does not affect the amino acid sequence at all.

Going further:

Students could research sickle cell anaemia as an example of a point mutation:

The gene that makes part of the haemoglobin molecule, which carries oxygen around the body, has substituted an adenine for a thymine. So the code in the DNA sequence reads CAC instead of CTC. As a result, the codon on the mRNA reads GUG instead of CAG. This makes the matching amino acid valine rather than glutamic acid. This means a slightly deformed haemoglobin is produced, which doesn’t work as effectively.

Discuss the affect any type of genetic mutation has if it occurs in the first three bases of a DNA sequence for a particular gene.

Discuss how some substitutions lead to beneficial or silent alleles as they have no negative affect on the protein created.

Teacher notes

1.11 Genes can be tested

Pages 30–31

Introducing the topic:

Genetic screening and testing is carried out to determine if individuals have a particular genetic disease or condition. This has advantages in the treatment of the disease, however, there are many social and ethical issues that arise when considering genetic screening and testing.

Teaching tip:

Remind students that the discussion or debate on genetic testing is not a competition with a winner or loser. Allow students to express their opinions fully without interruption (everyone has an equal voice). If conflict arises during the discussion, it must be resolved in a manner that retains everyone’s dignity. Critique ideas, not people.

Teaching tip:

One of the biggest issues resulting from genetic screening is who owns the information. The Human Genome Project was completed in 2003. This was a combined project with many research individuals and companies from around the world contributing by sequencing small sections of DNA donated by volunteers. The data was then put together by the US Department of Energy and the US National Institutes of Health to create a vast databank of the sequences of the three billion chemical base pairs that make up human DNA. Many countries have developed laws that protect individuals from discrimination on the basis of genetic testing; however, this is yet to be tested.

Additional activity: investigating disorder screenings

Investigate the different disorders that are screened for at birth and the importance of testing for newborn babies.

Going further:

Research the genetic disorders that are tested and screened for in Australia compared to other countries.

You may like to use the following website for further information on understanding genetic testing in Australia:

<http://www.genetics.edu.au/Genetic-conditions-support-groups/Understanding-Genetic-Testing>

Teacher notes

1.12 Genes can be manipulated

Pages 32–33

Introducing the topic:

DNA is universal to all organisms. Humans have created technologies enabling us to manipulate DNA to produce protein products or organisms which have a survival advantage in the environment. Transgenic organisms are created by inserting foreign DNA into their genome while genetically modified organisms have had their DNA modified in some way.

Teaching tip:

Highlight the importance of the universal nature of DNA to biotechnology. The only difference between the genetic material of a bacteria cell and ourselves is the sequence of the nucleotides.

Additional activity: DNA molecule exercise

Create a recombinant DNA molecule from a gene and plasmid that have been cut with the same restriction enzyme. Use scissors for your restriction enzyme and sticky tape for your ligase to permanently join them together.

Additional activity: debate

Debate:

• That genetically modified food is dangerous to our health.

• That transgenic organisms are harmful to the environment.

Going further:

Investigate the importance of restriction enzymes in creating recombinant DNA.

Select different restriction enzymes to splice genes and plasmids to create transgenic organisms.

<http://www.mhhe.com/biosci/genbio/virtual_labs/BL_22/BL_22.html>

Teacher notes

1.13 Genetic engineering is used in medicine

Pages 34–35

Introducing the topic:

Genetic engineering is the process of changing the genetic code of an organism. Gene cloning uses this process to produce multiple copies of a particular gene. This can be done to mass produce proteins such as insulin. Gene therapy involves the insertion of a healthy version of a gene into the chromosomes of an individual with a defective gene.

Teaching tip:

The ability to communicate theories based on facts is an important part of science. Often articles in the media express an opinion instead of the facts. Students must learn to identify which argument is opinion and which is scientific fact.

Additional activity: stem cells

Research the different types of stem cell in greater detail:

<http://stemcells.nih.gov/info/basics/pages/basics10.aspx>

Additional activity: word card dominoes

Play dominoes using word cards that are divided into two piles. Start with one word laid out on the table. Each team takes it in turns to lay down a card. When the card is laid down the student must say how they relate their card with the card it touches. (This ends up being a large mind map.)

Additional activity: creating a Venn diagram

Create a Venn diagram to compare and contrast gene cloning and gene transfer.

Prepare a debate, that:

• Cloning of all animals should be banned.

• Gene therapy of humans should be banned.

• Gene therapy is dangerous.

• Parents should be able use genetic therapy of an embryo to ensure a healthy baby.