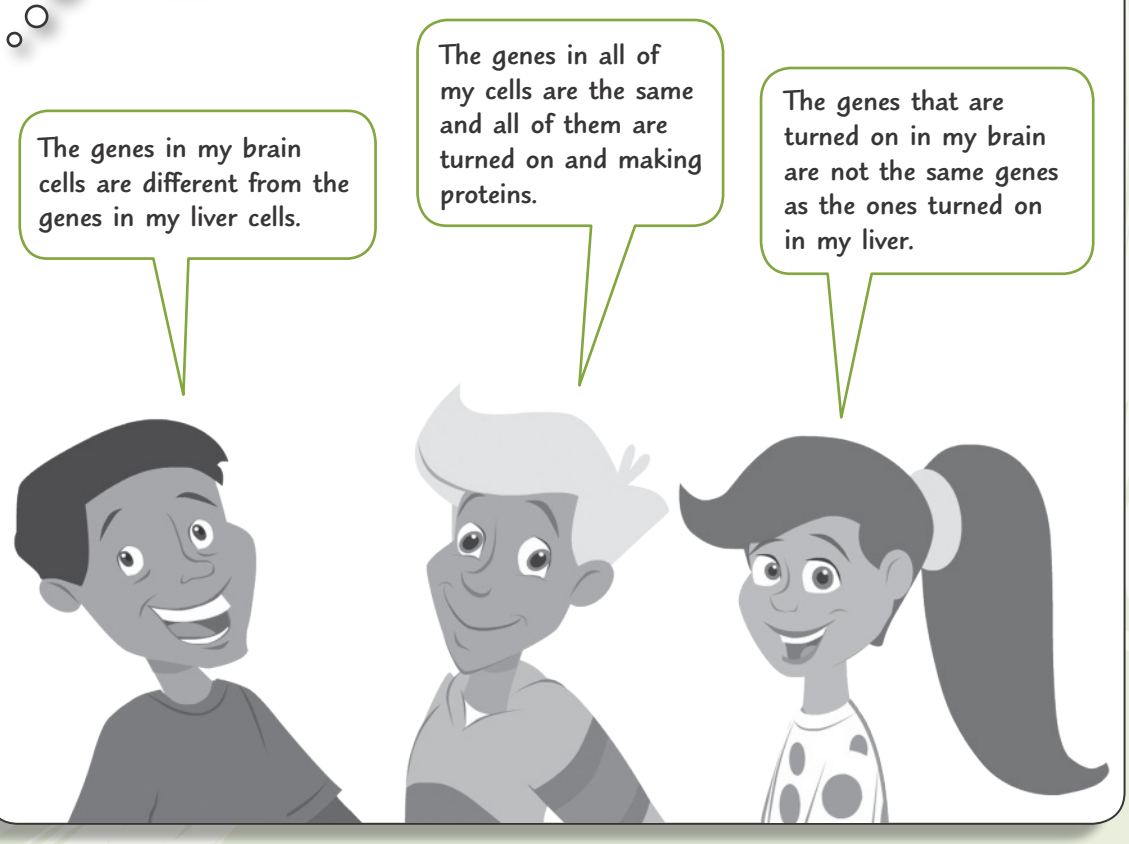
Genetic Continuity

TOPIC 3

What do You Think?

Genes in Cells



TOPIC 3

Genetic Continuity

Vocabulary

asexual reproduction	egg	replicate
biotechnology	expressed	selective breeding
body cell	genes	sexual reproduction
bond	genetic engineering	sperm
chromosome	genetic recombination	subunit
clone	heredity	template
DNA	mutation	traits

Topic Overview

When two organisms reproduce, their offspring receive genetic instructions, called **genes**, from each parent. The genes determine which **traits**—or characteristics—each offspring will have. All organisms—whether they are animals, plants, or members of one of the other kingdoms—pass their genetic characteristics along in this manner. Because of this transfer of genetic information, offspring tend to resemble their parents.

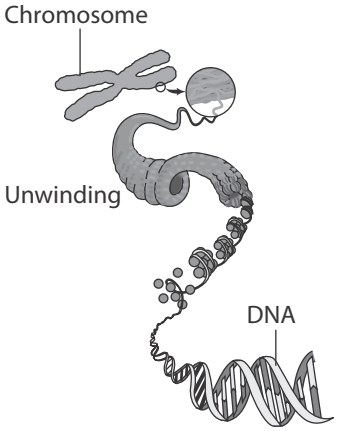


Figure 3-1. Chromosomes contain DNA: Notice that the chromosome contains one very long double strand of DNA.

Heredity and Genes

Heredity is the passing of genetic information from one generation to the next through reproduction. The hereditary information (**DNA**) is organized in the form of genes located in the **chromosomes** of each cell. Recall that chromosomes, which are found in the cell nuclei, contain the DNA molecules. (See Figure 3-1.) It is the DNA molecules that carry the genetic information of the cell.

A human cell contains many thousands of genes in its nucleus, and each gene carries a separate piece of coded information. The traits inherited by an individual can be determined by one pair of genes or by several pairs of genes. It is also true that a single gene pair can sometimes influence more than one trait. Table 3-1 shows several examples of these variations.

Table 3-1. Human Traits Inherited with Different Numbers of Genes

Trait	Number of Gene Pairs Needed to Affect Trait
Cystic fibrosis	Single gene pair
Skin color	Multiple gene pairs
Sickle cell disease	Single gene pair affecting multiple traits

Some traits that an organism inherits are readily observable. These include traits such as hair color, leaf shape, flower scent, and wing structure. The overall structure of the body is also an observable trait that is inherited from the parents. Some children, for example, inherit long, slender toes or large ear lobes.

Other traits are not so obvious. Less obvious traits may involve a defective heart, a single kidney, or

how some of the body's chemicals function. Examples include the ability to produce insulin, the types of receptors present on a cell membrane, and whether an individual can make a particular respiratory enzyme.

Methods of Reproduction

There are two common methods of reproduction: asexual and sexual. The major difference between these two methods is whether one or two parents are involved in producing the offspring. **Asexual reproduction** involves one parent or individual (often a single-celled organism); **sexual reproduction** involves two parents.

Asexual Reproduction In organisms that reproduce asexually, all the genetic instructions (genes) come from one individual or parent. Since the genes are all from one parent, offspring are usually identical to the parent.

Because the coded instructions in their cells are the same as the instructions in their parent's cells, asexually produced offspring are genetically identical to their parents. Identical genetic copies are known as **clones.** Because they are asexually produced, entire populations of bacteria—perhaps millions of cells—may be genetically identical clones.

Sexual Reproduction In organisms that reproduce sexually, two parents are required to produce offspring. Each parent produces sex cells. **Sperm** are the sex cells produced by the male; the **egg** is the sex cell produced by the female. Recall that genes in **body cells**—cells other than sex cells—occur in pairs, but each sex cell contains only one gene from each pair. The offspring that results from sexual reproduction therefore receives half of its genetic information from the female parent (via the egg) and half from the male parent (via the sperm).

Genetic Recombination When a sperm and egg combine to form a new cell with a complete set of genetic instructions, a unique combination of genes results. The term for this is **genetic recombination.** This unique combination of thousands of genes produces an offspring that may resemble either or both parents in many ways but will not be identical to either of them.

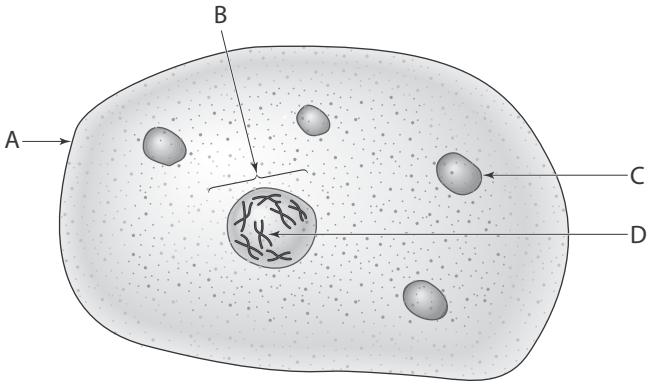
Digging Deeper

Sometimes people use the word *gene* when they really mean *allele*. A gene is actually an area or part of a chromosome with coded information about some trait or characteristic of the organism. In many cases, there are two or more ways for this trait to appear. The alternate forms of the genes are the alleles—the actual information contained in the gene.

In pea plants, for example, genes carry information about the color of their seeds. However, the seeds can be either green or yellow. The actual color of the seeds will be determined by the alleles. If the plant has two alleles with genetic instructions for yellow seeds, the seeds will be yellow. If they both have genetic instructions for green, the seeds will be green. However, if there is one allele for yellow and one for green, the seeds will be . . . yellow. In this case, the yellow allele is referred to as the dominant allele.

Review Questions Set 3.1

1. A cell is represented in the diagram below.



Which statement about the cell is correct?

(1) Structure A synthesizes and secretes cellular products.
(2) Structure B contains chromosomes involved in transmitting genetic information.
(3) Structure C utilizes DNA in the process of photosynthesis.
(4) Structure D is the site of protein synthesis.

2. Which materials are composed of DNA?

(1) proteins
(2) genes
(3) nerve secretions
(4) fluid in vacuoles

3. In an animal cell, DNA is found in the greatest concentration in the

(1) vacuole
(2) ribosome
(3) nucleus
(4) cytoplasm

4. Cystic fibrosis is a genetic disease. Examine the illustration below.

Father with cystic fibrosis
Father has two abnormal genes for the trait

Mother who does not have cystic fibrosis
Mother has ???

Child with cystic fibrosis
Child has two abnormal genes for the trait

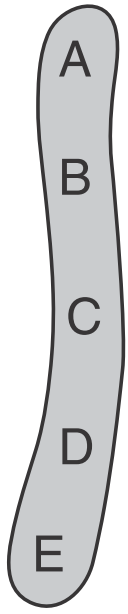
The mother's cells most likely contained

(1) a disease-causing virus
(2) one normal gene and one abnormal gene
(3) two normal genes
(4) an abnormal number of chromosomes

5. Bacteria in culture A produce slime capsules around their cell walls. A biologist removed the DNA from some of the bacteria in culture A. He then injected it into bacteria in culture B, which normally do not produce slime capsules. After the injection, bacteria with slime capsules began to appear in culture B. What conclusion could best be drawn from this investigation?

(1) The bacteria in culture A are mutations.
(2) Bacteria reproduce faster when they have slime capsules.
(3) The slime capsules of bacteria in culture B contain DNA.
(4) DNA is most likely involved in the production of slime capsules.

6. The letters in the diagram below represent genes on a particular chromosome.



Gene *B* contains the code for an enzyme that cannot be synthesized unless gene *A* is also active. Which statement best explains why this can occur?

(1) A hereditary trait can be determined by more than one gene.
(2) Genes are made up of double-stranded segments of DNA.
(3) All the genes on a chromosome act to produce a single trait.
(4) The first gene on each chromosome controls all the other genes on the chromosome.

7. Which cell structure includes all of the others?

(1) nucleus
(2) gene
(3) DNA
(4) chromosome

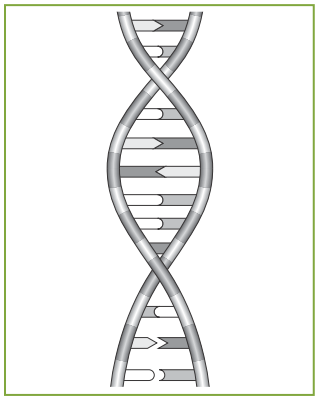


Figure 3-2. Model of a section of a DNA molecule

The Genetic Code

The inherited instructions (genes) that are passed from parent to offspring exist in the form of a chemical code. This genetic code, as the chemical code is called, is contained in the DNA molecules of all organisms. DNA molecules resemble a flexible, twisted ladder formed from many smaller repeating units, as shown in Figure 3-2.

DNA Structure

Like other large molecules of life, the DNA molecule is made of thousands of smaller sections called **subunits.** Each subunit has three chemical parts: a sugar, a phosphate, and a base. The subunits vary from one another according to the kind of bases they contain. The bases are represented by the letters A, G, C, and T. The four subunits of DNA molecules are

arranged in pairs, each subunit forming one side and half of one rung of the "twisted ladder." Base A of one subunit always pairs with the base T of another subunit. In a similar way, base G always pairs with base C. Figure 3-3 shows the details of the structure in an untwisted molecule.

Once the chemical and structural properties of DNA were discovered by scientists, it became clear how this molecule could contain a kind of message that functions as a code. Notice in Figure 3-3 that the sequence of bases on this molecule's left strand, reading from top to bottom, is ACAG. A different molecule might have a sequence in the same position reading GCAG or AACG. The specific sequence of bases in a DNA molecule forms a coded message. The message of a single gene is often a sequence of hundreds of bases. The code for an entire human is estimated to be around 3 billion base pairs!

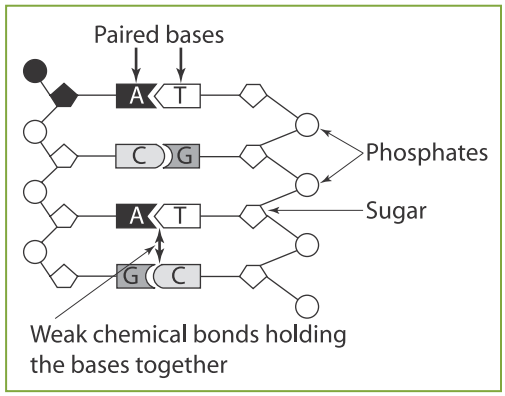


Figure 3-3. Portion of a DNA molecule: A single subunit is shown in black. The bases of the DNA molecule are arranged in pairs, represented here by letters. The base pairs form the rungs of the twisted DNA ladder. The sugar and phosphate of each subunit form the sides of the ladder and are connected by strong chemical bonds. The two sides are held together by weak chemical bonds between the paired bases. (Bonds are the links between atoms that hold molecules together.)

DNA Replication

The ability to copy the coded instructions in the DNA molecule is critical to its function. Knowing the chemical makeup and structure of DNA molecules gave scientists an immediate clue to how the molecule could be copied, or **replicated.** When scientists realized that the bases used weak chemical bonds to pair with each other, they also realized that the DNA could separate at that weak **bond** to form two single strands. Each single strand became a **template**, or pattern, for a new molecule.

The new molecule was built by attaching new subunits to each template strand, always following the base pairing rules of linking A with T and C with G. The result is the formation of two new molecules whose base pair sequences are exactly alike. See Figure 3-4.

When the structure of DNA was determined, scientists finally understood how cells could copy and transfer information to new cells each time they divide and to new offspring during reproduction. Replication produces two identical copies of the cell's genetic information, each ready to be passed from the parent cell to two offspring cells during cell division. Offspring cells are commonly called daughter cells.

Proteins and Cell Functioning

The work of the cell is carried out by the many types of molecules the cell assembles (synthesizes). Many of these molecules are proteins. Protein molecules are long chains. They are formed from various combinations of 20 kinds of amino acids arranged in a specific sequence.

The sequence of amino acids in a particular protein influences the shape of the molecule. This is because some of the amino acid parts are attracted to (and may bond with) other amino-acid parts of the chain. The connections that form between different parts of the chain cause it to fold and bend in a specific way. The final folded shape

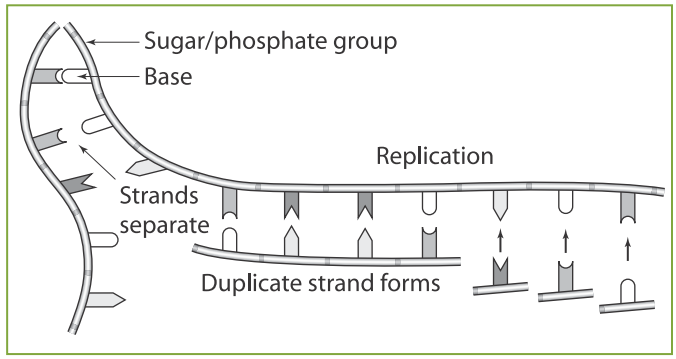


Figure 3-4. The replication of a DNA molecule: This is how cells copy their genetic information to be passed on to two offspring cells when cell division occurs. Both strands are replicated at the same time.

of the protein enables it to carry out its function in the cell. Many proteins made by a cell become enzymes that regulate chemical reactions. Remember that an enzyme can interact with a specific molecule because their shapes correspond.

Some of the proteins made in cells become parts of organelles, such as the cell membrane. Other proteins include the hormone insulin or the many antibodies that bind to antigen molecules on pathogens. The color of your eyes and skin are also the result of proteins synthesized by your body.

The DNA-Protein Connection

Cells store vast amounts of coded information in their genes. Much of this coded information is used to make the thousands of proteins that each cell requires for its functions and the structures it contains. The proteins for these structures and functions are made at the ribosomes according to the directions stored in the cell's DNA code.

Because offspring inherit genetic information from their parents, their cells make many of the same proteins. This is what causes the resemblance between some children and their parents. Making many of the same proteins causes both parent and offspring to form similar structures that give them similar features. One example of a protein-dependent trait includes hair texture (curly, straight, or kinky).

If a parent's DNA carries a code for a protein that does not function correctly, the children may also make that defective protein. For example, an albino does not produce the usual amount of eye, hair, or skin color pigment. The condition is caused by a defect in the gene that codes for the protein that produces color pigment. If albino parents pass this gene to their offspring, they, too, may not produce the normal color pigment.

Protein Synthesis The process of synthesizing a protein from DNA begins in the nucleus. There, the DNA code of a particular gene is "read" by a special enzyme and used to produce a "messenger" molecule. This messenger molecule then travels to the ribosomes in the cell's cytoplasm. With the aid of specialized transfer molecules, amino acids are moved to the ribosomes for assembly into protein. They are bonded in the order specified by the messenger molecule. In this way, the sequence of amino acids of any protein, and therefore its overall structure, is determined by the gene's DNA sequence in the nucleus. The process is shown in Figure 3-5.

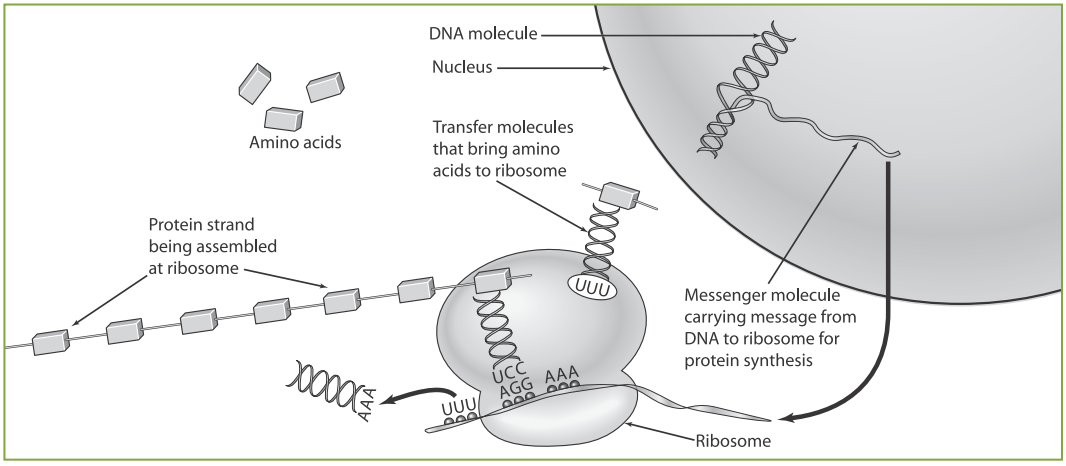


Figure 3-5. Protein synthesis: Notice that the DNA in the nucleus supplies the instructions for how to assemble the protein to the messenger molecule. The transfer molecules help assemble amino acids. The assembly process occurs at a ribosome.

8. In a DNA molecule, the letters A, T, C, and G represent

(1) bases
(2) sugars
(3) starches
(4) proteins

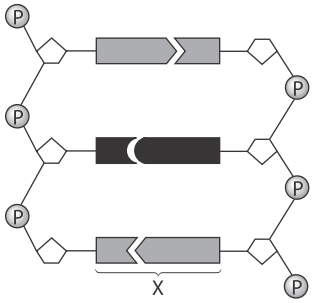
9. The individuality of an organism is determined by the organism's

(1) amino acids
(2) nitrogen bases
(3) DNA base sequence
(4) order of ribosomes

10. What would most likely happen if the ribosomes in a cell were not functioning?

(1) The cell would undergo uncontrolled mitotic cell division.
(2) The synthesis of enzymes would stop.
(3) The cell would produce antibodies.
(4) The rate of glucose transport in the cytoplasm would increase.

11. The diagram below represents a portion of a DNA molecule.



The letter X represents two bases that are

(1) identical and joined by weak bonds
(2) identical and joined by strong bonds
(3) a part of the genetic code of the organism
(4) amino acids used to build folded protein molecules

12. The kinds of genes an organism possesses are dependent on the

(1) type of proteins in the organism's nuclei
(2) sequence of bases in the organism's DNA
(3) number of ribosomes in the organism's cytoplasm
(4) size of the mitochondria in the organism's cells

13. What is the role of DNA molecules in the synthesis of proteins?

(1) They catalyze the formation of bonds between amino acids.
(2) They determine the sequence of amino acids in a protein.
(3) They transfer amino acids from the cytoplasm to the nucleus.
(4) They supply energy for protein synthesis.

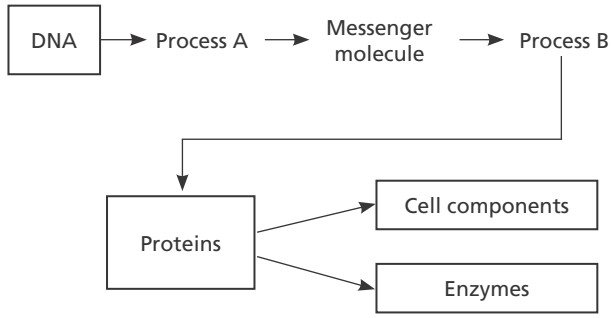
14. The diagram at the right represents a molecule of

(1) ATP
(2) protein
(3) carbohydrate
(4) DNA

15. During replication, the strands of a double-stranded DNA molecule separate when the bonds are broken between their paired bases.

Explain why, in terms of the genetic code, it is important that the molecule separate between the bases and not at some other point. [1]

Base your answers to questions 16 and 17 on the diagram below and on your knowledge of biology.



16. Within which organelle does process A occur?

(1) ribosome
(2) nucleus
(3) vacuole
(4) cell membrane

17. Within a living cell, which organelles are directly necessary for process B to occur?

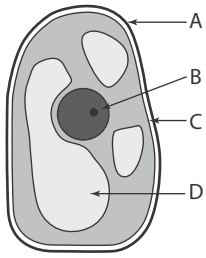
(1) ribosomes
(2) mitochondria
(3) vacuoles
(4) cell membranes

18. In all living cells, DNA controls cellular activities by

(1) determining the order of amino acids in protein molecules
(2) regulating the concentration of molecules on both sides of the cell membrane
(3) varying the rates of starch synthesis
(4) coordinating active and passive transport

19. Which cell organelle indicated in the diagram controls the synthesis of enzymes?

(1) A
(2) B
(3) C
(4) D



20. The sequence of amino acids that makes up a protein molecule is determined by the sequence of

(1) bases in DNA
(2) glucose in DNA
(3) ribosomes in the cytoplasm
(4) chloroplasts in the vacuoles

21. In DNA, the base represented by an A always pairs with the base represented by

(1) A (2) T (3) C (4) G

22. The presence of DNA is important for cellular metabolic activities because DNA

(1) directs the production of enzymes
(2) is a structural component of cell membranes
(3) directly increases the solubility of nutrients
(4) is a major component of the cytoplasm

Mutations

Genes are actually segments of DNA molecules. Any alteration of the DNA sequence is a **mutation**, which changes the normal message carried by the gene. Many mutations involve the substitution of one base for another. This often causes a different amino acid to be placed in a particular position in the growing protein chain. Some mutations involve the insertion of an additional base into an existing DNA sequence. This affects all of the code past the change, just as skipping a blank on the answer sheet for a test can cause all of the remaining answers to be shifted to the next blank, making almost all of them wrong. The deletion of a base from the normal gene sequence would also alter all the code past the change.

Some mutations occur when the bases within a gene are accidentally rearranged. This, too, alters the genetic code. Figure 3-6 shows several ways that DNA can mutate.

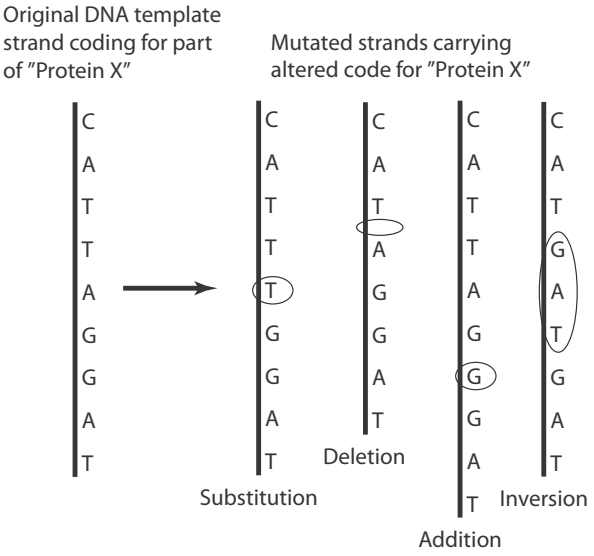


Figure 3-6. Mutation of DNA: The DNA on the left is part of the original template strand that codes for protein X. The four strands on the right show the DNA that would result from several types of mutations.

All of these alterations are totally random and can occur anywhere along the molecule, making the result of the change almost impossible to predict. However, when a DNA sequence is changed, it is quite likely that the protein it codes for may be assembled incorrectly. If some amino acids are replaced by others, or if their sequence is different, the folding of the protein may be different. Incorrect folding means that the protein's shape would not be normal. This could cause the protein to malfunction. One mutation caused by a substitution is sickle cell disease. (See Figure 3-7.)

Mutations can cause such serious changes that the cell may die. However, if a mutated cell does survive and can replicate its DNA, its changed instructions will be copied and passed on to every cell that develops from it. In sexually reproducing organisms, only mutations found in sex cells can be inherited by the offspring.

DNA and Individuality Although an individual's body cells all originally come from a single cell, the body is made up of many types of cells. Each body cell's nucleus—whether it is a nerve cell, skin cell, or bone cell—has a complete set of identical genetic instructions for that individual.

For years, scientists wondered how cells with identical genetic instructions could be so different. The answer is that each kind of cell uses only some of the genetic information it contains. It uses only the instructions it needs to operate its own kind of cell. For instance, information for building all of a person's enzymes is coded in the chromosomes of each cell, but a muscle cell uses only the specific enzymes that are needed by a muscle cell.

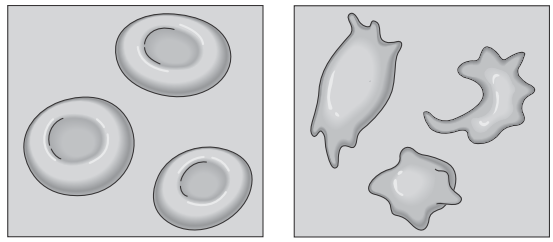


Figure 3-7. Effects of a substitution mutation: Normal red blood cells are round. The abnormal cell shapes are due to a substitution mutation that forms a defective protein which changes the cell's shape.

Both the internal and external environment of the cell can influence which genes are activated in that cell. Some of this influence may occur during development, leading to the many different types of cells that an organism needs.

The selective activation of genes in a cell may continue as conditions change throughout life. For instance, chemical signals from within the cell or from other cells may activate a particular gene. Hormones are one kind of molecule that can activate parts of a cell's DNA code, leading to the production of a particular protein.

Although genes are inherited, an organism's environment can affect the way some genes are revealed, or **expressed,** in the organism. For example, in some animals, such as the Himalayan rabbit, the outside temperature can cause the activation or inactivation of the genes for fur color. When the rabbit's body area is cold, black fur grows. If the same body area becomes warm, white fur grows instead. (See Figure 3-8.) The environment can also influence human genes. Studies of identical twins (those with identical genetic information) who were raised in different environments show that they have differences that can only be explained by the influence of the environment on gene expression.

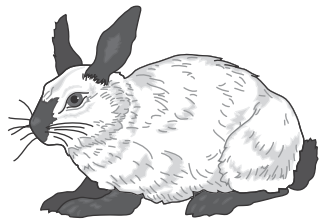


Figure 3-8. Body temperature and fur color in the Himalayan rabbit: From what you know about the activation and inactivation of the genes for fur color in this animal, why do you think the ears, feet, nose, and tail are black?

Review Questions Set 3.3

23. A dog breeder can determine that the sudden appearance of hairlessness in one of the puppies is a mutation if the dog

(1) is still hairless after 5 years
(2) shows no change in the hairless condition after its diet is changed
(3) develops other conspicuous differences from the parent
(4) is bred and the trait is capable of being inherited

24. Explain how a change in the sequence of nitrogen bases in a DNA molecule could result in a gene mutation. [1]

25. Which mutation could be passed on to future generations?

(1) a gene change in a liver cell
(2) cancer caused by excessive exposure to the sun
(3) a chromosomal alteration during gamete formation
(4) random breakage of a chromosome in a leaf cell of a maple tree

26. Mutations can be transmitted to the next generation if they are present in

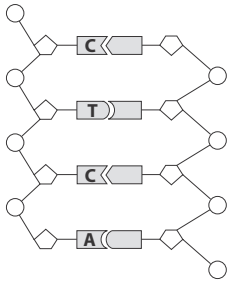
(1) brain cells
(2) sex cells
(3) body cells
(4) muscle cells

27. Overexposure of animals to X-rays is dangerous because X-rays are known to damage DNA. A direct result of this damage is cells with

(1) unusually thick cell walls
(2) no organelles located in the cytoplasm
(3) abnormally large chloroplasts
(4) changes in chromosome structure

28. The diagram below shows a portion of a DNA molecule. The base sequence of the unlabeled strand shown in the diagram is *most* likely

(1) G-A-G-T
(2) C-U-C-A
(3) T-C-T-G
(4) G-A-G-U



29. The individuality of an organism is determined by the

(1) sequence of bases in DNA
(2) number of amino acids in a cell
(3) position of ribosomes in the cytoplasm
(4) number of bases in the mitochondria

30. In which situation could a mutation be passed on to the offspring of one of the organisms listed in the data table below?

Data Table	
Name of Organism	**Number of Chromosomes in a Body Cell**
Human	46
Fruit fly	8

(1) Ultraviolet radiation causes fruit-fly wing cells to undergo uncontrolled division, resulting in cells with 9 chromosomes.
(2) A cell in the wall of the human uterus undergoes a change, resulting in cells with 47 chromosomes.
(3) A primary sex cell in a human forms a sperm that contains 23 chromosomes.
(4) A cell in the ovary of the fruit fly undergoes a chromosomal change that results in 5 chromosomes per egg cell.

31. A change in the sequence of bases in a DNA molecule is most accurately referred to as

(1) an insertion, deletion, or substitution
(2) a chromosomal replication
(3) carbohydrate molecule synthesis
(4) selective breeding

Genetic Engineering

Genetic engineering is a new technology that humans use to alter the genetic instructions in organisms. The idea of altering organisms to have more desirable traits, however, is not new. In fact, **biotechnology**—the application of technology to biological science—has been producing useful products for thousands of years. Cheese and bread are just two examples of "biotech" products made with the use of microbes.

Throughout recorded history, humans have also used **selective breeding**—a process that produces domestic animals and new varieties of plants with traits that are particularly desirable. Many meat products, for example, come from animals that have been bred to contain less fat. In addition, many of the fruits and vegetables we consume have been selectively bred to be larger, sweeter, hardier, or even juicier.

To breed a better plant, farmers might select a bean plant that produces many pods and then crossbreed it with a bean plant that resists fungus infections. The farmers would expect to get seeds that would grow into bean plants with both features.

Gene Manipulation

In recent years, plants and animals have been genetically engineered by manipulating their DNA instructions. The result of this genetic

manipulation is new characteristics and new varieties of organisms. Consequently, we have been able to produce plants with many beneficial traits. In one instance, plants can now contain genes with the instructions for making chemicals that kill the insects that feed on them. Scientists have also engineered bacteria that can be used to clean up oil spills or that produce human growth hormone.

The basic method that alters genes in organisms uses special enzymes. These enzymes cut DNA segments in a way that allows the segments to be spliced, or moved and attached, to the DNA of a new organism. Once in the new organism, the transferred genes direct the new organism's cells to make the same protein product as the original organism. For example, when we move a human insulin-producing gene into a bacterial cell, the bacterium—and all its offspring—will produce human insulin. This provides a way to produce large quantities of a hormone at low cost. Genes for other human proteins have also been inserted into bacterial cells, as illustrated in Figure 3-9.

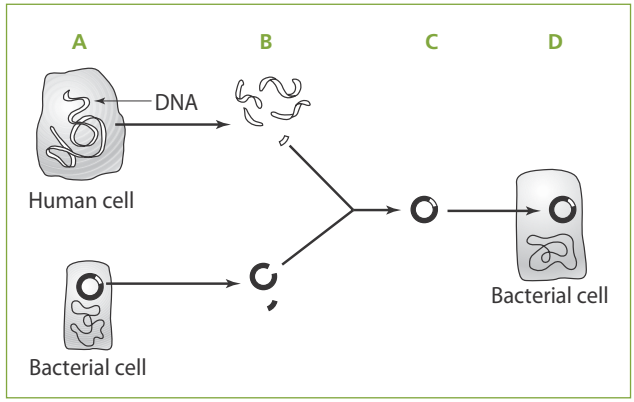


Figure 3-9. Genetic engineering using bacteria: On the left (area A), a special enzyme is used to cut a segment of DNA from a human cell and to also cut open a circular piece of DNA from a bacterial cell. When the piece of human DNA is mixed with the open loop of bacterial DNA (area B), they join to form a closed loop (area C). That loop is then taken up by another bacterial cell (area D). The transformed bacterial cell will produce the protein product of the human DNA segment and that DNA loop will be duplicated and passed to all future offspring.

Other enzymes have been found that can be used to make many copies of segments of DNA. These can be used to increase the amount of DNA available from a tiny sample. This procedure is helpful even when only a drop of blood or saliva is found at a crime scene. By copying and re-copying the DNA in the sample, criminal investigators can produce a sample that is large enough to test. The test results may identify or clear suspects.

Applications of Biotechnology

The health care field has much to gain through our increasing knowledge of genetics and biotechnology. New methods enable us to locate and decode genes that cause diseases. Once we have a better understanding of the gene's specific defect, we may be able to develop ways to treat the disease. In some cases, we may be able to alter the DNA in affected cells and cure the person.

Due to mutations in their genes, people with genetic diseases are sometimes unable to produce certain hormones, enzymes, or other body chemicals. At times, we can extract these chemicals from animals, such as sheep and cattle. These extractions, however, can be expensive, and the chemicals may contain contaminants that cause side effects. If scientists can produce the chemicals using genetically engineered organisms, we may be able to economically provide the missing chemicals in a pure enough form to avoid the side effects associated with chemicals obtained from animal sources.

32. Genetic engineering is used in the biotechnology industry to

(1) eliminate all infections in livestock
(2) synthesize hormones such as insulin and human growth hormone
(3) increase the frequency of fertilization
(4) eliminate asexual reproduction

33. Describe two examples of how an understanding of genetics is making new fields of health care (treatment or diagnosis) possible. [1]

34. The insertion of a human DNA fragment into a bacterial cell might make it possible

(1) for the bacterial cell to produce a human protein
(2) to clone the human that donated that DNA fragment
(3) for humans to become immune to an infection by this type of bacteria
(4) to clone this type of bacteria

35. In a DNA sample, 15% of the bases are thymine (T). What percentage of the bases in this sample are cytosine (C)?

(1) 15% (3) 35%
(2) 30% (4) 85%

Base your answers to questions 36 through 40 on the passage below and on your knowledge of biology.

Advances with Cells and Genes

Recent advances in cell technology and gene transplanting have allowed scientists to perform some interesting experiments, including splicing human DNA into the chromosomes of bacteria. The altered bacteria express the added genes.

Bacteria reproduce rapidly under certain conditions. This means that bacteria with the gene for human insulin could multiply rapidly, resulting in a huge bacterial population capable of producing large quantities of human insulin.

The traditional source of insulin has been the pancreases of slaughtered animals. Continued use of this insulin can trigger allergic reactions in some humans. The new bacteria-produced insulin is actually human insulin. As a result, it does not produce many side effects.

The bacteria used for these experiments are *E. coli*, which are found in the digestive system of humans and many other animals. Some scientists question these experiments and are concerned that the altered *E. coli* may accidentally get into water supplies.

For each of the statements below, write the number 1 if the statement is true according to the passage, the number 2 if the statement is false according to the passage, or the number 3 if not enough information is given in the passage.

36. Transplanting genetic material into bacteria is a simple task. [1]

37. Under certain conditions, bacteria reproduce at a rapid rate. [1]

38. The continued use of insulin from animals may cause harmful side effects in some people. [1]

39. The bacteria used in these experiments are normally found only in the nerve tissue of humans. [1]

40. Bacteria other than *E. coli* are unable to produce insulin. [1]

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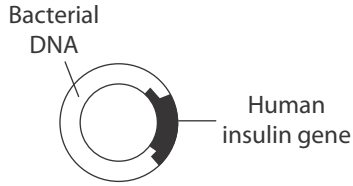
41. The headline "Improved Soybeans Produce Healthier Vegetable Oils" accompanies an article describing how a biotechnology company controls the types of lipids (fats) present in soybeans. The improved soybeans are most likely being developed by the process of

(1) natural selection
(2) asexual reproduction
(3) genetic engineering
(4) habitat modification

42. A product of genetic engineering technology is represented below.



Which substance was needed to join the insulin gene to the bacterial DNA as shown?

(1) a specific carbohydrate
(2) a specific enzyme
(3) hormones
(4) antibodies

43. In the past, diabetics used horse or cow insulin to control their glucose levels. Today, as a result of genetic engineering, human insulin can be synthesized by bacteria. State *one* advantage for a person with diabetes to receive genetically engineered insulin rather than insulin taken from a horse or cow. [1]

Directions

Review the Test-Taking Strategies section of this book. Then answer the following questions. Read each question carefully and answer with a correct choice or response.

Part A

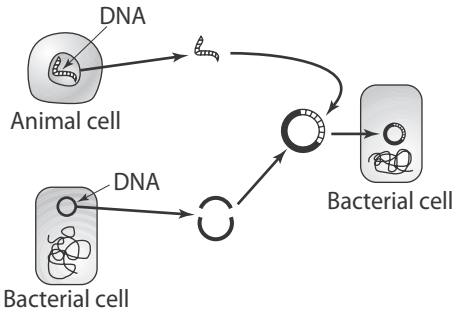
1 Hereditary information for most traits is generally located in
(1) genes found on chromosomes
(2) chromosomes found on genes
(3) the ribosomes of sperm cells
(4) the mitochondria in the cytoplasm

2 An analysis of chromosomes in a culture containing mutated cells may show the loss of one or more bases making up the chromosome. This type of chromosomal change is known as
(1) an addition
(2) an insertion
(3) a deletion
(4) a substitution

3 What is the genetic engineering technique in which DNA is transferred from the cells of one organism to the cells of another organism?
(1) gene splicing
(2) chromatography
(3) electrophoresis
(4) selective deleting

4 A change that alters the base sequence in an organism's DNA is a
(1) mutation
(2) replication
(3) clone
(4) zygote

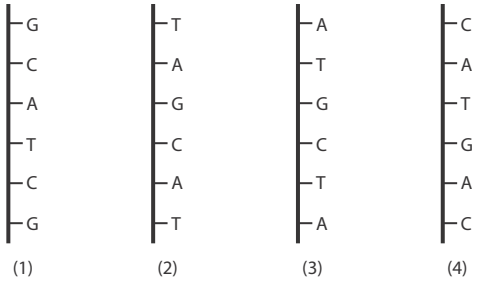
5 The technique illustrated in the diagram is known as



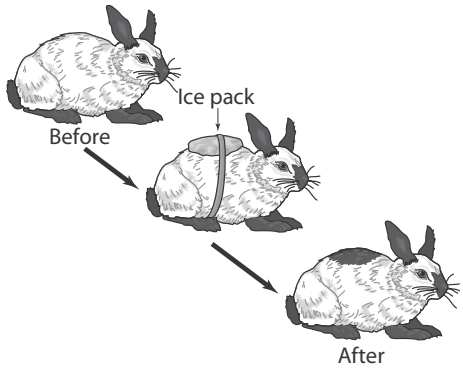
(1) genetic engineering
(2) protein synthesis
(3) internal fertilization
(4) external fertilization

6 The diagram represents a portion of DNA.

Which DNA strand could correctly pair with the one illustrated?



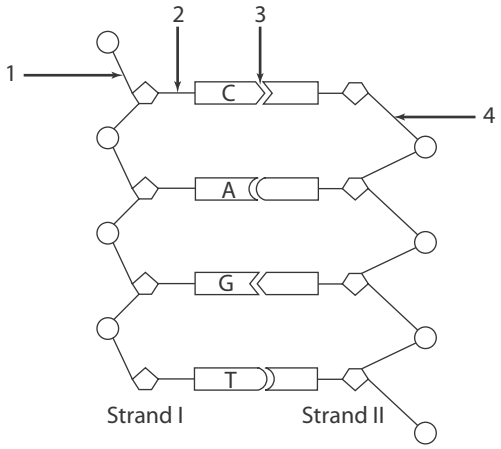
7 The diagram illustrates what happens to the fur color of a Himalayan rabbit after prolonged exposure to a low temperature.



The change in fur color is most likely due to
(1) the effect of heredity on gene expression
(2) the arrangement of genes on chromosomes
(3) environmental influences on gene action
(4) mutations resulting from a change in the environment

Part B

Base your answers to questions 8 and 9 on the diagram below and on your knowledge of biology. The diagram represents part of a double-stranded DNA molecule.



8 The base sequence of Strand II is most likely
(1) C–G–G–A
(2) G–A–G–T
(3) G–T–C–A
(4) T–G–A–C

9 Which event must occur if a nucleus containing this molecule is to undergo mitotic cell division?
(1) The bonds at point 3 break, and the molecule replicates.
(2) The molecule separates at point 2, and new bases attach.
(3) The bonds at point 3 break, and the molecule deletes bases.
(4) The bonds at points 1, 2, and 4 break, and new sequences of bases form.

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10 Identify the process by which information in segments of human DNA can be expressed by a bacterial cell. [1]

Base your answers to questions 11 and 12 on the information below and on your knowledge of biology.

Some geneticists are suggesting the possibility of transferring some of the genes that influence photosynthesis from an efficient variety of crop plant to a less efficient crop plant. The goal is to produce a new variety with improved productivity.

11 To produce this new variety, the project would most likely involve
(1) genetic engineering
(2) a gene mutation
(3) chromatography
(4) vaccinations

12 Which technique would most likely be used to produce large numbers of genetically identical offspring from this new variety of plant?
(1) cloning
(2) sexual reproduction
(3) electrophoresis
(4) selective breeding

Base your answers to questions 13 through 17 on the information and data table below and on your knowledge of biology.

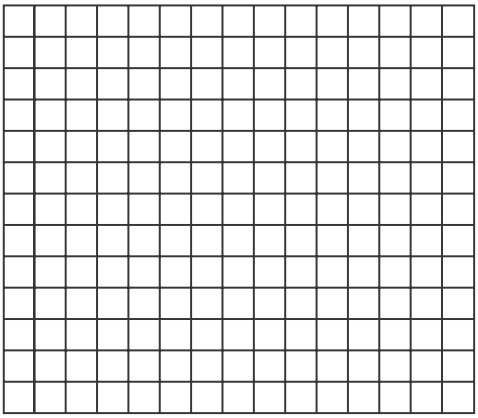
Certain chemicals cause mutations in cells by breaking chromosomes into pieces. Cells containing such broken chromosomes are known as mutated cells. Certain nutrients, such as beta carotene (a form of vitamin A), have the ability to prevent chromosome breakage by such mutagenic chemicals.

The results of an investigation of the effect of beta carotene in preventing chromosome damage are presented in the following data table. In the investigation, varying amounts of beta carotene per kilogram of body weight were added to the diets of hamsters. A mutagenic chemical at a constant dose rate was also added to the diets of the hamsters.

The Effect of Beta Carotene Added to Hamster Diet on Cell Mutation

Amount of Beta Carotene per Kilogram of Hamster's Body Weight	Percentage of Mutated Cells
0 mg	11.5
20 mg	11.0
30 mg	8.0
40 mg	7.0
50 mg	4.5
75 mg	3.5
100 mg	2.0
150 mg	1.2

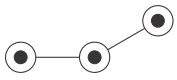
Using the information in the data table, construct a line graph on the grid provided. Follow the directions given.



13 Mark an appropriate scale, without any breaks, on each of the axes. [1]

14 Label the axes. [1]

15 Plot the data from the table. Surround each point with a small circle and connect the points. [1]

Example: 

16 State an appropriate conclusion for the above experiment regarding the use of beta carotene for the prevention of chromosome damage. Use experimental data to support your conclusion. [1]

17 Vitamins A and E are essential vitamins that can dissolve in oil. A student, knowing this and seeing the above results with beta carotene, suggested that vitamin E will increase the percentage of mutations in the cells of hamsters. State whether or not this is a valid conclusion. Support your statement with an explanation. [1]

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18 Animal cells utilize many different proteins. Discuss the synthesis of proteins in an animal cell. Your answer must include at least:

- the identity of the building blocks required to synthesize these proteins [1]
- the identity of the sites in the cell where the proteins are assembled [1]
- an explanation of the role of DNA in the process of making proteins in the cell [1]

Part C

Base your answers to questions 19 through 23 on the passage below and on your knowledge of biology.

Genetic Engineering

Genetic engineering is a technique used by scientists to combine or splice genetic material from different organisms. Gene splicing involves changing the normal base sequences of DNA by removing a section of DNA and introducing another gene. The technique may involve the use of the bacterium *E. coli*. The bacterium has one large chromosome and several small plasmids, which are ring-shaped pieces of DNA found in the cytoplasm.

Genetic engineers have been able to extract plasmids from *E. coli*. Restriction enzymes are used to cut the DNA of the plasmid at designated places in the base sequence. The same enzymes are used to cut a section of human DNA. This section of human DNA is then placed into the space in the cut DNA of the bacterial plasmid. The human DNA codes for the synthesis of a product such as human growth hormone.

The spliced bacterial DNA, which now contains a piece of human DNA, is referred to as a hybrid. This hybridized plasmid is then taken in by *E. coli* cells. When the bacterium reproduces, the hybrid DNA will replicate. The offspring will possess the ability to synthesize the human growth hormone.

19 Describe a bacterial plasmid. [1]

20 Describe a hybrid plasmid. [1]

21 Explain how genetic engineers remove sections from human DNA for splicing into bacterial DNA. [1]

22 State one benefit of gene splicing. [1]

23 Explain why it is not necessary to continue splicing the gene for human growth hormone into *E. coli* once cultures of the bacteria with the spliced gene are established. [1]

Base your answers to questions 24 through 26 on the statement below and on your knowledge of biology.

Selective breeding has been used to improve the racing ability of horses.

24 Define selective breeding.

25 State how selective breeding would be used to improve the racing ability of horses. [1]

26 State *one disadvantage* of selective breeding. [1]

27–28 Knowledge of human genes gained from research on the structure and function of human genetic material has led to improvements in medicine and health care for humans.

- state two ways this knowledge has improved medicine and health care for humans [1]
- identify one specific concern that could result from the application of this knowledge [1]

Base your answers to questions 29 and 30 on the information below and on your knowledge of biology.

A biologist at an agriculture laboratory is asked to develop a better quality blueberry plant. He is given plants that produce unusually large blueberries and plants that produce very sweet blueberries.

29 Describe one way the biologist could use these blueberry plants to develop a plant with blueberries that are both large and sweet. [1]

30 The biologist is successful in producing the new plant. State one method that can be used to produce many identical blueberry plants of this new type. [1]

Base your answer to question 31–34 on the information below and on your knowledge of biology.

Chickens as Drug Factories

Scientists in Scotland have successfully produced five generations of chickens that lay eggs containing certain protein-based drugs. The scientists changed the DNA of the chickens so that two drugs, one used to treat skin cancer and the other used to treat multiple sclerosis, were present in the egg whites. Cows, sheep, and goats have already been altered to produce protein-based drugs in their milk. Chickens are considered good "drug factories" because they are inexpensive to care for, they grow fast, and their chicks inherit the special drug-producing ability.

31–34 Discuss the process scientists used to alter the DNA of the chickens. In your answer, be sure to:

- state one reason why the scientists altered the DNA of the chickens instead of altering a protein already present in the chickens [1]
- identify the type of molecule used to cut the gene from the DNA of another organism and move it into the chicken's DNA [1]
- state one advantage of using chickens for this procedure [1]
- state one reason why some people might not support this method of drug production [1]

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35 One variety of wheat is resistant to disease. Another variety contains more nutrients of benefit to humans. Explain how a new variety of wheat with disease resistance and high nutrient value could be developed. In your answer, be sure to:

- identify one technique that could be used to combine disease resistance and high nutrient value in a new variety of wheat [1]
- describe how this technique would be carried out to produce a wheat plant with the desired characteristics [1]
- describe one specific difficulty (other than stating that it does not always work) in developing a new variety using this technique [1]