Week 13

AP Biology

Homework bundle for this week

本周作业合集

exercises.lol

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AP Biology Name: _____ Score: _____

1. What does **meiosis** produce?
   - ☐ gametes (sex cells) with half the chromosome number
   - ☐ two identical body cells
   - ☐ ATP
   - ☐ proteins
2. In **crossing over**, what happens?
   - ☐ matching chromosomes swap sections of DNA
   - ☐ the cell makes ATP
   - ☐ DNA is destroyed
   - ☐ the cell stops dividing
3. An **allele** is…
   - ☐ one version of a gene
   - ☐ a whole chromosome
   - ☐ a type of protein
   - ☐ a kind of cell
4. In **incomplete dominance**, a red and a white flower can give offspring that are…
   - ☐ pink — a blend of the two
   - ☐ always red
   - ☐ always white
   - ☐ blue
5. An organism's **phenotype** is shaped by…
   - ☐ both its genotype and its environment
   - ☐ only its genotype
   - ☐ only its environment
   - ☐ neither
6. Meiosis involves two divisions, producing four cells from one.

   ☐ True ☐ False

7. Genetic diversity helps a population survive changing conditions.

   ☐ True ☐ False

8. The set of alleles an organism carries is its _____ (its genetic make-up).

   _____

9. Some genes, like the human blood group gene, have more than two possible alleles.

   ☐ True ☐ False

10. Human height depends on both genes and environment (such as nutrition).

    ☐ True ☐ False

5. Heredity

Answers · 答案

AP Biology

1. **gametes (sex cells) with half the chromosome number**

   Meiosis makes **gametes** — sex cells with half the normal chromosome number.

2. **matching chromosomes swap sections of DNA**

   In **crossing over**, homologous chromosomes exchange matching sections, creating new gene combinations.

3. **one version of a gene**

   An **allele** is one version of a **gene** — for example, a version for brown eyes or blue eyes.

4. **pink — a blend of the two**

   In **incomplete dominance** neither allele fully dominates, so the heterozygote is a blend — pink.

5. **both its genotype and its environment**

   The **phenotype** is the result of the **genotype** *and* the **environment** working together.

6. **True**

   Meiosis I and meiosis II together split one cell into four haploid gametes.

7. **True**

   Variety means some individuals may cope with a new challenge — the raw material for evolution.

8. **genotype**

   The **genotype** is the alleles present; the **phenotype** is the trait you can see.

9. **True**

   The ABO gene has three alleles (A, B, O) — an example of **multiple alleles**.

10. **True**

    Genes set a possible range for height; nutrition and health decide where within it you end up.

AP BIOLOGY • EXERCISE SHEET

5.1 Meiosis

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

KEY WORDS meiosis 减数分裂 • gametes 配子 • haploid 单倍体

Objective

Build the skills to answer exam questions on **meiosis**.

You must be able to:

- describe **meiosis** 减数分裂 producing four **haploid** 单倍体 gametes
- contrast meiosis with mitosis
- explain the reduction from diploid to haploid

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

What meiosis does

Meiosis makes **gametes** (sex cells). One **diploid** (2n) cell divides **twice** to make **four haploid** (n) cells, each with **half** the chromosome number.

Two divisions

- **Meiosis I** separates **homologous pairs** (halving the chromosome number).
- **Meiosis II** separates sister chromatids (like mitosis).

Meiosis vs mitosis

- **Mitosis** — one division, two identical **diploid** cells (growth/repair).
- **Meiosis** — two divisions, four genetically varied **haploid** cells (reproduction).

Restoring diploidy

At fertilization, two haploid gametes fuse to restore the **diploid** number — which is why gametes must be haploid.

2 Practice

Now apply the methods above.

2.1 How many cells does one meiosis produce, and are they haploid or diploid? [2]

2.2 What is separated in meiosis I? [1]

2.3 State one difference between meiosis and mitosis. [1]

3 Exam-style questions

3.1 Meiosis produces gametes that are [1]

- **A** diploid and identical
- **B** haploid and varied
- **C** diploid and varied
- **D** haploid and identical

3.2 A diploid cell with 8 chromosomes undergoes meiosis.

(a) How many chromosomes will each gamete have? [1]

(b) Explain why gametes must be haploid. [2]

3.3 Compare the products of mitosis and meiosis in terms of number, ploidy, and variation. [3]

Solutions

2.1 Four cells; haploid.

2.2 Homologous pairs of chromosomes.

2.3 Any one: meiosis has two divisions / makes four haploid varied cells vs mitosis' one division making two identical diploid cells.

3.1 B — haploid and varied.

3.2 (a) 4 chromosomes. (b) At fertilization two gametes fuse; if they were diploid the chromosome number would double each generation, so they must be haploid to keep it constant.

3.3 Mitosis: 2 cells, diploid, genetically identical; meiosis: 4 cells, haploid, genetically varied.

The following information applies to all parts.

---

2. Eukaryotic cells use small interfering RNA (siRNA) molecules that regulate the expression of certain genes by binding to complementary sequences in target mRNAs. This binding causes the protein AGO2 to cleave the target mRNAs. As a result of the cleavage, the mRNAs are not translated.

Part A

Describe one location where ribosomes are found in eukaryotic cells.

The following information applies to parts B, C, and D.

To investigate the role of AGO2 in the cleavage of mRNA transcribed from two genes, Gene *G* and Gene *H*, scientists determined the amount of Gene *G* and Gene *H* mRNA produced in cells with three different *AGO2* genotypes:

- Homozygous for the wild-type AGO2 protein ($AGO2^{+/+}$)
- Heterozygous for the allele encoding a nonfunctional AGO2 protein ($AGO2^{+/-}$)
- Homozygous for the allele encoding a nonfunctional AGO2 protein ($AGO2^{-/-}$)

The scientists then calculated the amount of Gene *G* and Gene *H* mRNA produced from cells of each genotype relative to that in $AGO2^{+/+}$ cells. These results are shown in the table.

Relative Average Amounts of Gene *G* and Gene *H* mRNA in Cells with Different *AGO2* Genotypes

	mRNA in $AGO2^{+/+}$ Cells $\pm$ $SE_{\bar{x}}$	mRNA in $AGO2^{+/-}$ Cells $\pm$ $SE_{\bar{x}}$	mRNA in $AGO2^{-/-}$ Cells $\pm$ $SE_{\bar{x}}$
Gene *G*	1.0 ± 0.1	0.9 ± 0.4	1.5 ± 0.5
Gene *H*	1.0 ± 0.1	2.0 ± 0.1	3.0 ± 0.4

Part B

i. Using the template in the space provided for your response, **construct** a bar graph that represents the data in the table. Your graph should be appropriately plotted and labeled.

ii. Based on the table, **determine** all the cells in which the amount of Gene *G* mRNA produced is statistically the same as the amount in the cells with the $AGO2^{+/+}$ genotype.

Part C

i. Based on the table, **describe** the relationship between the number of wild-type copies of the *AGO2* gene and the amount of Gene *H* mRNA in the cells.

ii. Based on the data in the table for Gene *H*, **calculate** the percent by which the average amount of mRNA in $AGO2^{-/-}$ cells increases compared with that in $AGO2^{+/-}$ cells.

Part D

i. The scientists claim that siRNA binding and AGO2 cleavage of mRNAs play a greater role in the regulation of Gene *H* expression than in the regulation of Gene *G* expression. Based on the table, **support** the scientists' claim.

ii. Anaphase I of meiosis is blocked in mice with the $AGO2^{-/-}$ genotype. Scientists hypothesize that the block in meiosis occurs because the continued presence of a spindle-fiber stabilizing protein prevents the chromosomes from separating. Based on the table, **explain** how the $AGO2^{-/-}$ genotype could cause this effect on the dividing cells.

The following information applies to all parts.

---

4. The process of meiosis enables animals that reproduce sexually to produce gametes.

Part A

Describe one characteristic of chromosome movement during Meiosis I.

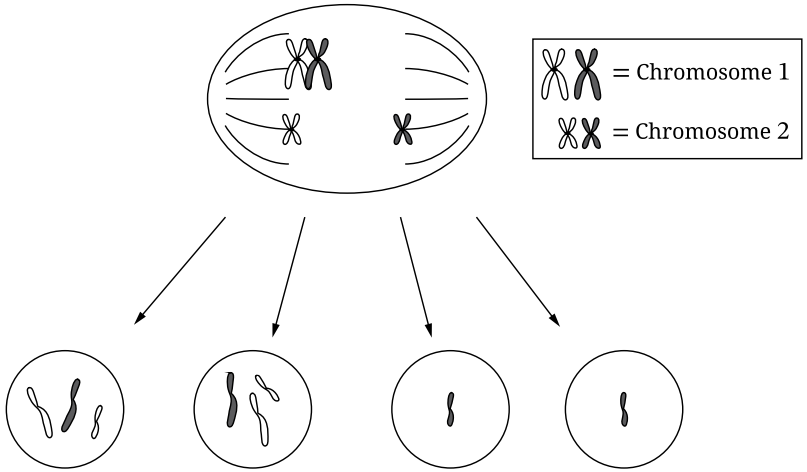
Part B

Explain why chromosomes are more visible when viewed under a microscope during mitosis or meiosis than at any other time in the cell cycle.

Part C

An animal cell with two pairs of homologous chromosomes (a diploid number of four) has undergone meiosis to produce four gametes, and an error occurred at one step, as shown in the figure. One set of chromosomes is represented in white, and the other set is represented in gray.

An Animal Cell Undergoing Meiosis



Assume that each gamete produced by the cell shown in the figure is fertilized by a gamete with a complete haploid set of chromosomes. Also assume gene regulation on Chromosome 1 is not affected by the number of copies of Chromosome 1 in the four resulting viable zygotes. **Predict** the difference in mRNA production from genes on Chromosome 1 among the four possible zygotes.

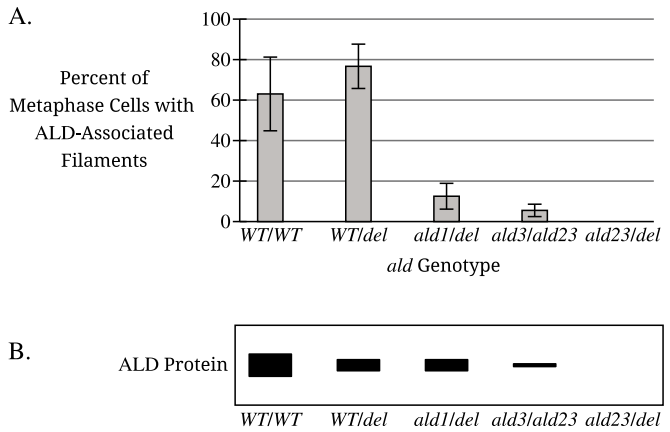
Part D

Triploidy describes a condition in which an organism has three complete sets of chromosomes in each cell. Provide reasoning to **justify** the claim that most organisms with triploidy cannot produce gametes with the chromosome number typical of the species.

6. The *ald* gene of fruit flies encodes the ALD protein, which is associated with both the centromeres of chromosomes and protein filaments produced during meiosis. In the absence of functional ALD proteins, gamete-producing cells enter anaphase I before homologous chromosomes are correctly aligned. As a result, the gametes produced do not contain the correct numbers of chromosomes.

Scientists generated four mutations in the *ald* gene: *ald1*, *ald3*, *ald23*, and *del*, which was a deletion of the gene. To study the role of the ALD protein in meiosis, scientists used gameteforming metaphase cells from groups of flies with different *ald* genotypes. Some of the flies were homozygous for the wild-type allele of *ald*: *WT/WT*. Other flies were heterozygous for different *ald* alleles: *WT/del*; *ald1/del*; *ald3/ald23*; *ald23/del*. The scientists measured the percent of metaphase cells that contained ALD-associated filaments (Figure 1A) and the amount of ALD protein produced by each of the cell types (Figure 1B).

Figure 1. (A) The average percent of gamete-forming metaphase cells that contained filaments associated with ALD and (B) the amount of ALD protein produced by each cell type. A thicker band indicates a greater amount of ALD protein.



A. Based on Figure 1A, **identify** the fly genotype in which the average percent of metaphase cells with ALD-associated filaments is close to 12%.

B. Based on Figure 1B, **describe** the difference in ALD protein production between gamete-forming metaphase cells of flies with the genotype *ald3/ald23* and flies with the genotype *ald23/del*.

C. Scientists hypothesize that gamete-forming metaphase cells can produce a normal amount of ALD-associated filaments even when they produce about half as much ALD protein as the wild-type cells produce. Use the data in Figures 1A and 1B to **support** the scientists' hypothesis.

D. For gamete-forming metaphase cells of the *WT/del* and *ald1/del* flies, **explain** why the phenotypes observed in Figure 1A differ even though the amount of ALD protein produced (Figure 1B) does not.

STOP

END OF EXAM

1. Crossing over in meiosis I is required for homologous chromosomes to properly align during metaphase and segregate during the first cell division.

(a)

(i) **Describe** the function of S phase of interphase.

Some regions of a chromosome called hotspots display a higher frequency of crossing over than other regions do. Crossing over is suppressed in chromosomal regions near the centromeres. The centromere region of a duplicated chromosome includes a collection of proteins that form a structure called the kinetochore. Scientists hypothesized that one or more of these kinetochore proteins are responsible for suppressing crossing over around the centromere.

To investigate their hypothesis, scientists modified chromosome 8 in yeast such that, in each cell, one chromosome from the pair of homologous chromosome 8s contained the gene encoding red fluorescent protein (RFP), while the other chromosome from the pair contained the gene encoding green fluorescent protein (GFP). Cells expressing RFP emit (give off) red light, and cells expressing GFP emit green light. Models of the modified chromosome 8 both before and after crossing over are shown in Figure 1.

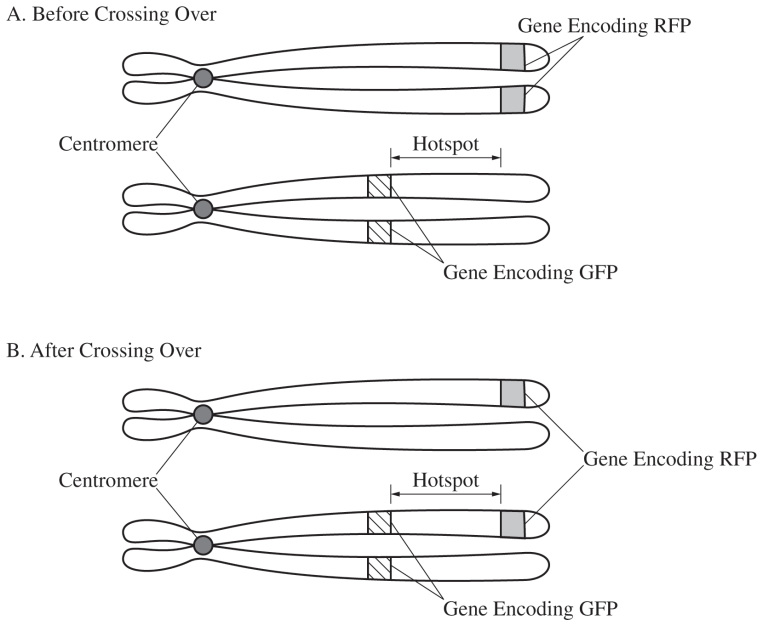


Figure 1. Models of modified chromosome 8 used in the experiment (A) before and (B) after crossing over occurs at the hotspot

(ii) **Explain** why some haploid cells formed after meiosis in this experiment will have only one fluorescent marker.

The scientists then investigated whether attaching individual kinetochore proteins to a specific DNA sequence present in a known crossing-over hotspot on chromosome 8 affected the frequency of crossing over at this location. In their first experiment, they examined three groups of yeast cells containing the modified chromosome 8. Group 1 contained no kinetochore proteins attached to the hotspot, group 2 contained the kinetochore protein CTF attached to the hotspot, and group 3 contained the kinetochore protein IML attached to the hotspot. For each group, the scientists determined the frequency of crossing over between the RFP and GFP genes. To determine the frequency, the scientists added the number of cells emitting both red and green light to the number of cells that emitted no light and divided by the total number of cells (Figure 2).

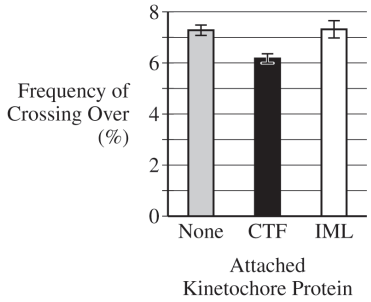


Figure 2. The frequency of crossing over in a hotspot on yeast chromosome 8 for cell groups treated with different kinetochore proteins. Error bars represent $\pm 2SE_{\bar{x}}$.

(b)

(i) **Identify** the control group for the scientists' first experiment, shown in Figure 2.

(ii) In a follow-up experiment, the scientists created a modified version of CTF in which the DNA-binding portion had been removed. They compared the frequency of crossing over in yeast cells in the presence and absence of unmodified CTF with that in yeast cells in the presence and absence of the modified CTF protein (data not shown). In the follow-up experiment, **justify** why the scientists used a modified CTF protein that is unable to bind to DNA as a control.

(iii) **Identify** the independent variable in the follow-up experiment.

(c) Based on Figure 2, **describe** the effect on the frequency of crossing over when CTF is attached to the chromosome 8 hotspot compared with the effect when IML is attached to the hotspot.

(d)

(i) **Predict** the effect on the number of copies of chromosome 8 likely to be present in the resulting daughter cells when CTF is attached to the hotspot.

(ii) Provide reasoning to **justify** your prediction.

(iii) **Explain** how the presence of hotspots (Figure 1) could increase the likelihood that a population will survive in the presence of selective pressures.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

If there are multiple parts to this question. write the part letter with your response.

2. During meiosis, double-strand breaks occur in chromatids. The breaks are either repaired by the exchange of genetic material between homologous nonsister chromatids, which is the process known as crossing over (Figure 1A), or they are simply repaired without any crossing over (Figure 1B). Plant breeders developing new varieties of corn are interested in determining whether, in corn, a correlation exists between the number of meiotic double-strand chromatid breaks and the number of crossovers.

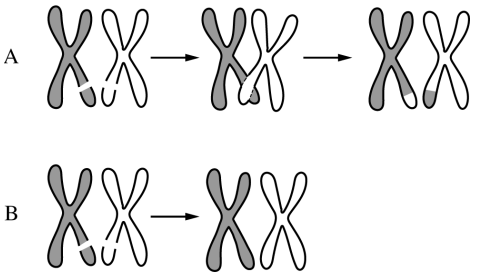


Figure 1. Double-strand breaks in chromatids are repaired with crossing over (A) or without crossing over (B).

Using specialized staining and microscopy techniques, scientists counted the number of double-strand chromatid breaks and the number of crossovers in the same number of meiotic gamete-forming cells of six inbred strains of corn (Table 1).

TABLE 1. NUMBER OF CHROMATID DOUBLE-STRAND BREAKS AND AVERAGE NUMBER OF CROSSOVERS IN INBRED STRAINS OF CORN

Strain of Corn	Number of Double-Strand Breaks	Average Number of Crossovers ($\pm 2SE_{\bar{x}}$)
I	710	19.5 ± 0.5
II	650	18.0 ± 0.7
III	600	17.5 ± 1.0
IV	510	16.0 ± 1.0
V	425	14.0 ± 0.5
VI	325	11.0 ± 1.5

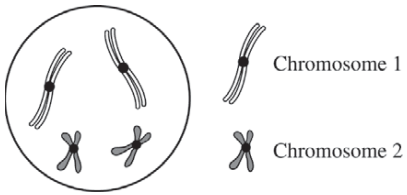
(a) The double-strand breaks occur along the DNA backbone. **Describe** the process by which the breaks occur.

(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1 and allows examination of a possible correlation between double-strand breaks and crossovers. Based on the data, **determine** whether corn strains I, II, and III differ in their average number of crossovers.

(c) Based on the data, **describe** the relationship between the average number of double-strand breaks and the average number of crossovers in the strains of corn analyzed in the experiment.

(d) Crossing over (Figure 1A) creates physical connections that are required for proper separation of homologous chromosomes during meiosis. A diploid cell with four pairs of homologous chromosomes undergoes meiosis to produce four haploid cells. Crossing over occurs between only three of the pairs. **Predict** the number of chromosomes most likely present in each of the four haploid cells. Provide reasoning to **justify** your prediction. **Explain** how plant breeders can use the information in Table 1 to help develop new varieties of corn.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

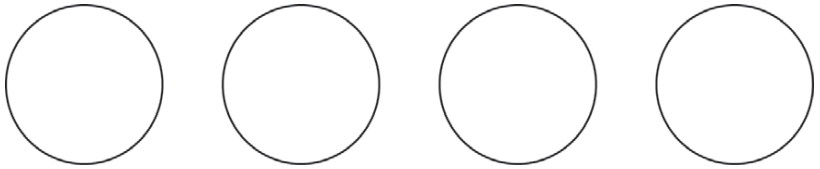


7. In a certain species of plant, the diploid number of chromosomes is 4 (2n = 4). Flower color is controlled by a single gene in which the green allele (*G*) is dominant to the purple allele (*g*). Plant height is controlled by a different gene in which the dwarf allele (*D*) is dominant to the tall allele (*d*). Individuals of the parental (P) generation with the genotypes *GGDD* and *ggdd* were crossed to produce F_1 progeny.

   (a) **Construct** a diagram below to depict the four possible normal products of meiosis that would be produced by the F_1 progeny. Show the chromosomes and the allele(s) they carry. Assume the genes are located on different chromosomes and the gene for flower color is on chromosome 1.

   (b) **Predict** the possible phenotypes and their ratios in the offspring of a testcross between an F_1 individual and a *ggdd* individual.

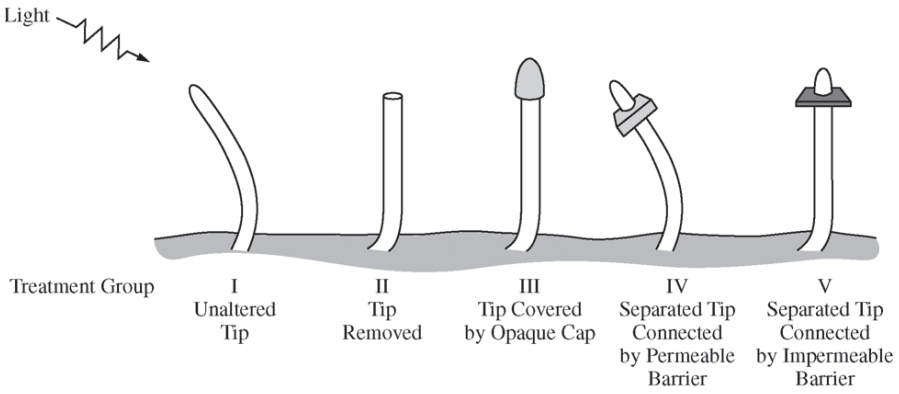
   (c) If the two genes were genetically linked, **describe** how the proportions of phenotypes of the resulting offspring would most likely differ from those of the testcross between an F_1 individual and a *ggdd* individual.



4. Both mitosis and meiosis are forms of cell division that produce daughter cells containing genetic information from the parent cell.

   (a) **Describe** TWO events that are common to both mitosis and meiosis that ensure the resulting daughter cells inherit the appropriate number of chromosomes.

   (b) The genetic composition of daughter cells produced by mitosis differs from that of the daughter cells produced by meiosis. **Describe** TWO features of the cell division processes that lead to these differences.



AP BIOLOGY • EXERCISE SHEET

5.2 Meiosis and Genetic Diversity

Name: _____ Class: _____ Date: _____ **Total: 12 marks**

KEY WORDS crossing over 交叉互换 • independent assortment 自由组合 • meiosis 减数分裂 • homologous chromosomes 同源染色体 • gametes 配子

Objective

Build the skills to answer exam questions on **meiosis and genetic diversity**.

You must be able to:

- explain **crossing over** 交叉互换 and **independent assortment** 自由组合
- explain how **random fertilization** adds variation
- link these to the diversity of offspring

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Three sources of variation

Meiosis and reproduction create genetic diversity by:

1. **Crossing over** — homologous chromosomes swap segments, making new gene combinations.
2. **Independent assortment** — homologous pairs line up randomly, so chromosomes are sorted into gametes in many combinations.
3. **Random fertilization** — any sperm can fertilize any egg.

■ Crossing over

During meiosis I, homologous chromosomes exchange pieces, so a chromosome ends up with a **new mix** of alleles from both parents.

■ Independent assortment

Each homologous pair lines up independently, so with n pairs there are 2^n possible gamete combinations from assortment alone.

■ A worked count

Humans have 23 pairs, giving 2^{23} (over 8 million) combinations from independent assortment — before crossing over and random fertilization add even more.

2 Practice

Now apply the methods above.

2.1 Name the process where homologous chromosomes swap segments. [1]

2.2 What does independent assortment describe? [1]

2.3 For an organism with 3 chromosome pairs, how many gamete combinations arise from independent assortment? [2]

3 Exam-style questions

3.1 Crossing over increases variation by [1]

- **A** copying DNA exactly
- **B** exchanging segments between homologous chromosomes
- **C** removing chromosomes
- **D** joining two gametes

3.2 A student lists sources of genetic variation.

(a) Name three sources from meiosis and reproduction. [3]

(b) Explain how independent assortment creates variation. [2]

3.3 Explain why sexual reproduction produces more genetic variation than asexual reproduction. [2]

Solutions

2.1 Crossing over.

2.2 Homologous pairs line up randomly, so chromosomes sort into gametes in many combinations.

2.3 $2^3 = 8$ combinations.

3.1 B — exchanging segments between homologous chromosomes.

3.2 (a) Crossing over, independent assortment, random fertilization. (b) Each homologous pair aligns independently, so the maternal and paternal chromosomes are mixed into gametes in many different combinations.

3.3 Sexual reproduction combines crossing over, independent assortment, and random fertilization to mix alleles from two parents, whereas asexual reproduction copies one parent's genome, giving little variation.

The following information applies to all parts.

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4. The process of meiosis enables animals that reproduce sexually to produce gametes.

Part A

Describe one characteristic of chromosome movement during Meiosis I.

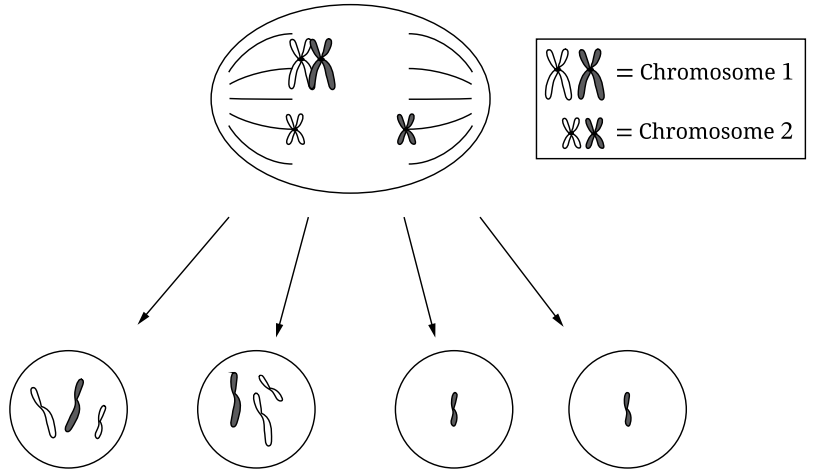
Part B

Explain why chromosomes are more visible when viewed under a microscope during mitosis or meiosis than at any other time in the cell cycle.

Part C

An animal cell with two pairs of homologous chromosomes (a diploid number of four) has undergone meiosis to produce four gametes, and an error occurred at one step, as shown in the figure. One set of chromosomes is represented in white, and the other set is represented in gray.

An Animal Cell Undergoing Meiosis



Assume that each gamete produced by the cell shown in the figure is fertilized by a gamete with a complete haploid set of chromosomes. Also assume gene regulation on Chromosome 1 is not affected by the number of copies of Chromosome 1 in the four resulting viable zygotes. **Predict** the difference in mRNA production from genes on Chromosome 1 among the four possible zygotes.

Part D

Triploidy describes a condition in which an organism has three complete sets of chromosomes in each cell. Provide reasoning to **justify** the claim that most organisms with triploidy cannot produce gametes with the chromosome number typical of the species.

1. Crossing over in meiosis I is required for homologous chromosomes to properly align during metaphase and segregate during the first cell division.

(a)

(i) **Describe** the function of S phase of interphase.

Some regions of a chromosome called hotspots display a higher frequency of crossing over than other regions do. Crossing over is suppressed in chromosomal regions near the centromeres. The centromere region of a duplicated chromosome includes a collection of proteins that form a structure called the kinetochore. Scientists hypothesized that one or more of these kinetochore proteins are responsible for suppressing crossing over around the centromere.

To investigate their hypothesis, scientists modified chromosome 8 in yeast such that, in each cell, one chromosome from the pair of homologous chromosome 8s contained the gene encoding red fluorescent protein (RFP), while the other chromosome from the pair contained the gene encoding green fluorescent protein (GFP). Cells expressing RFP emit (give off) red light, and cells expressing GFP emit green light. Models of the modified chromosome 8 both before and after crossing over are shown in Figure 1.

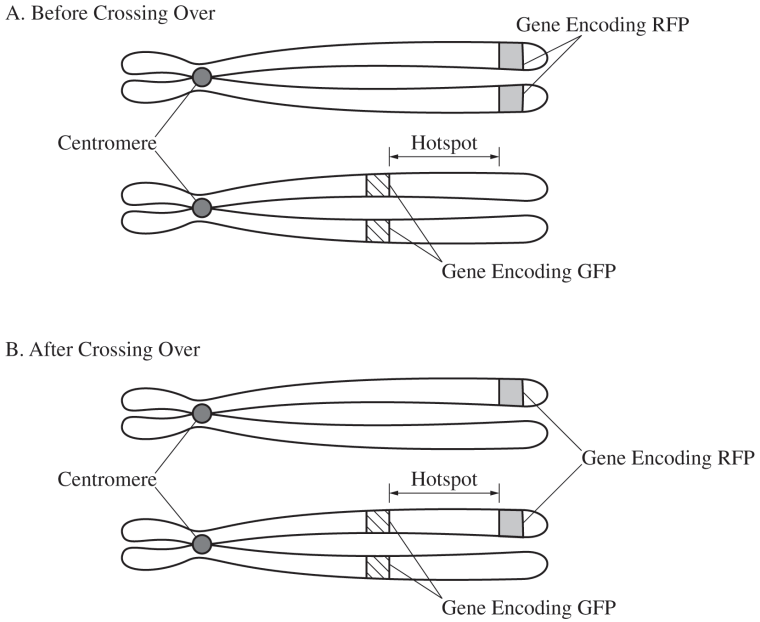


Figure 1. Models of modified chromosome 8 used in the experiment (A) before and (B) after crossing over occurs at the hotspot

(ii) **Explain** why some haploid cells formed after meiosis in this experiment will have only one fluorescent marker.

The scientists then investigated whether attaching individual kinetochore proteins to a specific DNA sequence present in a known crossing-over hotspot on chromosome 8 affected the frequency of crossing over at this location. In their first experiment, they examined three groups of yeast cells containing the modified chromosome 8. Group 1 contained no kinetochore proteins attached to the hotspot, group 2 contained the kinetochore protein CTF attached to the hotspot, and group 3 contained the kinetochore protein IML attached to the hotspot. For each group, the scientists determined the frequency of crossing over between the RFP and GFP genes. To determine the frequency, the scientists added the number of cells emitting both red and green light to the number of cells that emitted no light and divided by the total number of cells (Figure 2).

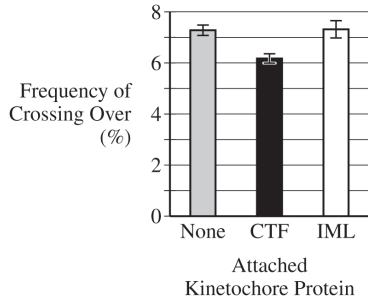


Figure 2. The frequency of crossing over in a hotspot on yeast chromosome 8 for cell groups treated with different kinetochore proteins. Error bars represent $\pm 2SE_{\bar{x}}$.

(b)

(i) **Identify** the control group for the scientists' first experiment, shown in Figure 2.

(ii) In a follow-up experiment, the scientists created a modified version of CTF in which the DNA-binding portion had been removed. They compared the frequency of crossing over in yeast cells in the presence and absence of unmodified CTF with that in yeast cells in the presence and absence of the modified CTF protein (data not shown). In the follow-up experiment, **justify** why the scientists used a modified CTF protein that is unable to bind to DNA as a control.

(iii) **Identify** the independent variable in the follow-up experiment.

(c) Based on Figure 2, **describe** the effect on the frequency of crossing over when CTF is attached to the chromosome 8 hotspot compared with the effect when IML is attached to the hotspot.

(d)

(i) **Predict** the effect on the number of copies of chromosome 8 likely to be present in the resulting daughter cells when CTF is attached to the hotspot.

(ii) Provide reasoning to **justify** your prediction.

(iii) **Explain** how the presence of hotspots (Figure 1) could increase the likelihood that a population will survive in the presence of selective pressures.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

If there are multiple parts to this question, write the part letter with your response.

2. During meiosis, double-strand breaks occur in chromatids. The breaks are either repaired by the exchange of genetic material between homologous nonsister chromatids, which is the process known as crossing over (Figure 1A), or they are simply repaired without any crossing over (Figure 1B). Plant breeders developing new varieties of corn are interested in determining whether, in corn, a correlation exists between the number of meiotic double-strand chromatid breaks and the number of crossovers.

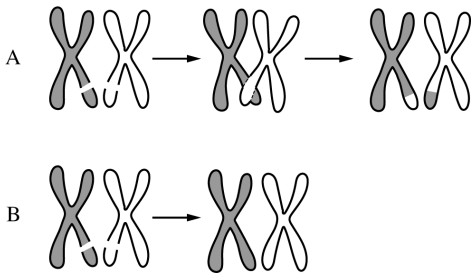


Figure 1. Double-strand breaks in chromatids are repaired with crossing over (A) or without crossing over (B).

Using specialized staining and microscopy techniques, scientists counted the number of double-strand chromatid breaks and the number of crossovers in the same number of meiotic gamete-forming cells of six inbred strains of corn (Table 1).

TABLE 1. NUMBER OF CHROMATID DOUBLE-STRAND BREAKS AND AVERAGE NUMBER OF CROSSOVERS IN INBRED STRAINS OF CORN

Strain of Corn	Number of Double-Strand Breaks	Average Number of Crossovers ($\pm 2SE_{\bar{x}}$)
I	710	19.5 ± 0.5
II	650	18.0 ± 0.7
III	600	17.5 ± 1.0
IV	510	16.0 ± 1.0
V	425	14.0 ± 0.5
VI	325	11.0 ± 1.5

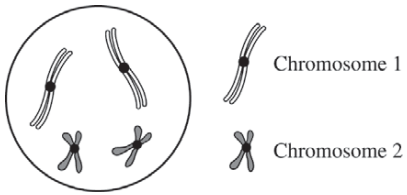
(a) The double-strand breaks occur along the DNA backbone. **Describe** the process by which the breaks occur.

(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1 and allows examination of a possible correlation between double-strand breaks and crossovers. Based on the data, **determine** whether corn strains I, II, and III differ in their average number of crossovers.

(c) Based on the data, **describe** the relationship between the average number of double-strand breaks and the average number of crossovers in the strains of corn analyzed in the experiment.

(d) Crossing over (Figure 1A) creates physical connections that are required for proper separation of homologous chromosomes during meiosis. A diploid cell with four pairs of homologous chromosomes undergoes meiosis to produce four haploid cells. Crossing over occurs between only three of the pairs. **Predict** the number of chromosomes most likely present in each of the four haploid cells. Provide reasoning to **justify** your prediction. **Explain** how plant breeders can use the information in Table 1 to help develop new varieties of corn.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

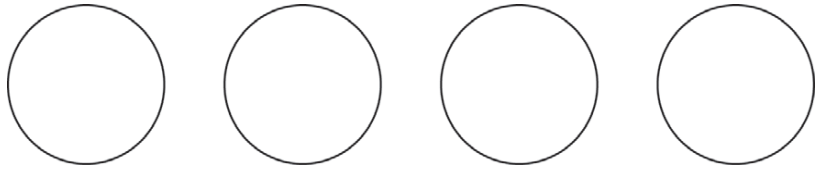


7. In a certain species of plant, the diploid number of chromosomes is 4 (2n = 4). Flower color is controlled by a single gene in which the green allele (*G*) is dominant to the purple allele (*g*). Plant height is controlled by a different gene in which the dwarf allele (*D*) is dominant to the tall allele (*d*). Individuals of the parental (P) generation with the genotypes *GGDD* and *ggdd* were crossed to produce F_1 progeny.

   (a) **Construct** a diagram below to depict the four possible normal products of meiosis that would be produced by the F_1 progeny. Show the chromosomes and the allele(s) they carry. Assume the genes are located on different chromosomes and the gene for flower color is on chromosome 1.

   (b) **Predict** the possible phenotypes and their ratios in the offspring of a testcross between an F_1 individual and a *ggdd* individual.

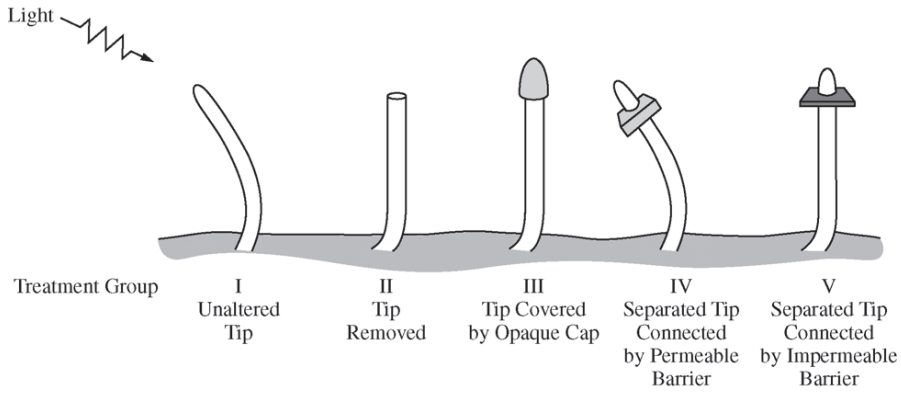
   (c) If the two genes were genetically linked, **describe** how the proportions of phenotypes of the resulting offspring would most likely differ from those of the testcross between an F_1 individual and a *ggdd* individual.



4. Both mitosis and meiosis are forms of cell division that produce daughter cells containing genetic information from the parent cell.

   (a) **Describe** TWO events that are common to both mitosis and meiosis that ensure the resulting daughter cells inherit the appropriate number of chromosomes.

   (b) The genetic composition of daughter cells produced by mitosis differs from that of the daughter cells produced by meiosis. **Describe** TWO features of the cell division processes that lead to these differences.



8. A research team has genetically engineered a strain of fruit flies to eliminate errors during DNA replication. The team claims that this will eliminate genetic variation in the engineered flies. A second research team claims that eliminating errors during DNA replication will not entirely eliminate genetic variation in the engineered flies.

   (a) **Provide** ONE piece of evidence that would indicate new genetic variation has occurred in the engineered flies.

   (b) **Describe** ONE mechanism that could lead to genetic variation in the engineered strain of flies.

   (c) **Describe** how genetic variation in a population contributes to the process of evolution in the population.

STOP

END OF EXAM

AP BIOLOGY • EXERCISE SHEET

5.3 Mendelian Genetics

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS phenotype 表现型 • genotype 基因型 • recessive 隐性 • dominant 显性 • alleles 等位基因

Objective

Build the skills to answer exam questions on **Mendelian genetics** — monohybrid crosses.

You must be able to:

- use **dominant** 显性 and **recessive** 隐性 alleles
- complete a **Punnett square** 庞纳特方格
- predict **genotype** 基因型 and **phenotype** 表现型 ratios

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Alleles and dominance

A **dominant** allele (capital, e.g. A) is expressed even with one copy; a **recessive** allele (a) is expressed only when **both** copies are recessive (aa).

■ The Punnett square

A **Punnett square** predicts offspring by crossing the parents' alleles. For $Aa \times Aa$:

	A	**a**
A	AA	Aa
a	Aa	aa

Genotypes: $1\,AA : 2\,Aa : 1\,aa$. Phenotypes: **3 dominant : 1 recessive**.

■ Genotype vs phenotype

- **Genotype** — the alleles present (AA, Aa, aa).
- **Phenotype** — the observable trait (dominant or recessive appearance).

■ A test cross

Crossing an unknown dominant ($A\_$) with aa: if any recessive offspring appear, the unknown was Aa.

2 Practice

Now apply the methods above.

2.1 How many recessive alleles are needed to show a recessive trait? [1]

2.2 For $Aa \times Aa$, state the phenotype ratio. [1]

2.3 What is the difference between genotype and phenotype? [1]

3 Exam-style questions

3.1 A cross $Aa \times Aa$ gives a phenotype ratio of [1]

- **A** 1:1
- **B** 3:1
- **C** 9:3:3:1
- **D** all dominant

3.2 In pea plants, tall (T) is dominant to short (t). Cross $Tt \times tt$.

(a) Complete a Punnett square. [2]

(b) State the genotype and phenotype ratios. [2]

3.3 A tall plant of unknown genotype is crossed with a short plant, and some short offspring appear. State the tall parent's genotype, with a reason. [2]

Solutions

2.1 Two.

2.2 3 dominant : 1 recessive.

2.3 Genotype is the alleles present; phenotype is the observable trait.

3.1 B — 3:1.

3.2 (a) Square gives Tt, Tt, tt, tt. (b) Genotype 1 Tt : 1 tt; phenotype 1 tall : 1 short.

3.3 Tt — a short offspring is tt, so it received a t from the tall parent, which must therefore carry a t.

BIOLOGY
Section II
Total Time—1 hour and 30 minutes
Reading Period—10 minutes
Writing Period—1 hour and 20 minutes
8 Questions

Directions: Questions 1 and 2 are long free-response questions that require about 22 minutes each to answer and are worth 10 points each. Questions 3–8 are short free-response questions that require about 6 minutes each to answer. Questions 3–5 are worth 4 points each and questions 6–8 are worth 3 points each.
Read each question carefully and completely. You are advised to spend the 10-minute reading period planning your answers. You may begin writing your responses before the reading period is over. Write your response in the space provided for each question. Only material written in the space provided will be scored. Answers must be written out in paragraph form. Outlines, bulleted lists, or diagrams alone are not acceptable.

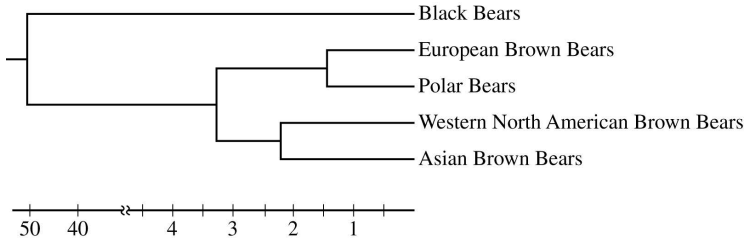


Figure 1. Phylogenetic tree representing the evolutionary relatedness among bear populations based on mitochondrial DNA sequence comparisons

1. Polar bears are highly adapted for life in cold climates around the North Pole. Brown bears, black bears, and pandas are found in warmer environments. Researchers collected complete mitochondrial DNA sequences from several populations of bears and constructed a phylogenetic tree to represent their evolutionary relatedness (Figure 1).

A researcher studying adaptation in bears sequenced the nuclear gene encoding a lysosomal trafficking protein (LYST) in polar bears, brown bears, black bears, and panda bears. There are seven inferred amino acid substitutions that are found only in polar bears. Mutations that cause similar substitutions in the human LYST protein are associated with Chediak-Higashi syndrome, an autosomal recessive condition in which pigment is absent from the hair and eyes. The researcher used the inferred amino acid sequences to build the distance matrix shown in Table 1.

TABLE 1. AMINO ACID DIFFERENCES IN THE LYST PROTEIN AMONG BEAR SPECIES

	Panda	Black	Brown	Polar
Panda	–			
Black	33	–		
Brown	34	1	–	
Polar	40	7	8	–

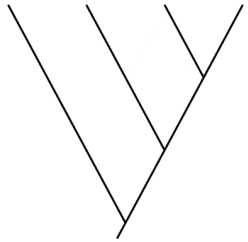
(a) Use the phylogenetic tree in Figure 1 to **estimate** the age in hundreds of thousands of years of the most recent common ancestor of all brown bears. **Identify** the population of brown bears to which polar bears are most closely related based on the mitochondrial DNA sequence comparison. **Identify** two populations whose positions could be switched without affecting the relationships illustrated in the phylogenetic tree.

(b) **Construct** a cladogram on the template to represent a model of the evolutionary relatedness among the bear species based on the differences in LYST protein sequences (Table 1). **Circle** the position on the cladogram that represents the out-group.

(c) A student claims that mitochondrial DNA sequence comparisons provide a more accurate phylogeny of bear species than do LYST protein sequence comparisons. **Provide ONE piece of reasoning** to support the student's claim.

(d) A researcher genetically engineers a mouse strain by deleting the mouse *lyst* gene and replacing it with the polar bear *lyst* gene. **Predict** the most likely difference in phenotype of the transgenic mouse strain compared to the wild-type mouse strain. **Justify** your prediction.

(e) **Describe** how the mutation in the *lyst* gene became common in the polar bear population. If the *lyst* gene were the only determinant of fur color, **predict** the percent of white offspring produced by a mating between a polar bear and a brown bear.



7. In the tongue sole fish (*Cynoglossus semilaevis*), sex is determined by a combination of genetics and environmental temperature. Genetically male fish have two Z chromosomes (ZZ), and genetically female fish have one Z chromosome and one W chromosome (ZW). When fish are raised at 22°C, ZZ fish develop into phenotypic males and ZW fish develop into phenotypic females. However, when fish are raised at 28°C, the Z chromosome is modified (denoted as Z*). Z*W individuals develop as phenotypic males that are fertile and can pass on the Z* chromosome to their offspring even when the offspring are raised at 22°C. A cross between a ZW female and a Z*Z male is shown in the Punnett square below.

	Z	W
Z*	Z* Z	Z* W
Z	Z Z	Z W

(a) **Predict** the percent of phenotypic males among the F_1 offspring of the cross shown in the Punnett square if the offspring are raised at 22°C.

(b) At least one Z or Z* chromosome is necessary for survival of the fish. A researcher crossed two fish and observed a 2:1 ratio of males to females among the offspring. Based on the information, **identify** the genotype of the male parent in the cross. **Describe** ONE fitness cost to the female of mating with this particular male.

3. Gibberellin is the primary plant hormone that promotes stem elongation. GA 3-beta-hydroxylase (GA3H) is the enzyme that catalyzes the reaction that converts a precursor of gibberellin to the active form of gibberellin. A mutation in the *GA3H* gene results in a short plant phenotype. When a pure-breeding tall plant is crossed with a pure-breeding short plant, all offspring in the F_1 generation are tall. When the F_1 plants are crossed with each other, 75 percent of the plants in the F_2 generation are tall and 25 percent of the plants are short.

Second Base in Codon

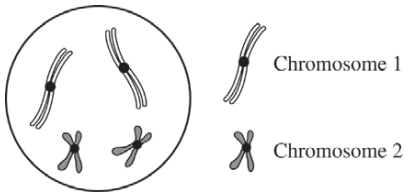
First Base in Codon	U	C	A	G	Third Base in Codon
U	UUU, UUC: Phe UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr UAA Stop, UAG Stop	UGU, UGC: Cys UGA Stop, UGG Trp	U C A G
C	CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His CAA, CAG: Gln	CGU, CGC, CGA, CGG: Arg	U C A G
A	AUU, AUC, AUA: Ile AUG: Met or Start	ACU, ACC, ACA, ACG: Thr	AAU, AAC: Asn AAA, AAG: Lys	AGU, AGC: Ser AGA, AGG: Arg	U C A G
G	GUU, GUC, GUA, GUG: Val	GCU, GCC, GCA, GCG: Ala	GAU, GAC: Asp GAA, GAG: Glu	GGU, GGC, GGA, GGG: Gly	U C A G

Figure 1. The universal genetic code

(a) The wild-type allele encodes a GA3H enzyme with alanine (Ala), a nonpolar amino acid, at position 229. The mutant allele encodes a GA3H enzyme with threonine (Thr), a polar amino acid, at position 229. **Describe** the effect of the mutation on the enzyme and **provide reasoning** to support how this mutation results in a short plant phenotype in homozygous recessive plants.

(b) Using the codon chart provided, **predict** the change in the codon sequence that resulted in the substitution of alanine for threonine at amino acid position 229.

(c) **Describe** how individuals with one (heterozygous) or two (homozygous) copies of the wild-type *GA3H* allele can have the same phenotype.



7. In a certain species of plant, the diploid number of chromosomes is 4 (2n = 4). Flower color is controlled by a single gene in which the green allele (*G*) is dominant to the purple allele (*g*). Plant height is controlled by a different gene in which the dwarf allele (*D*) is dominant to the tall allele (*d*). Individuals of the parental (P) generation with the genotypes *GGDD* and *ggdd* were crossed to produce F_1 progeny.

   (a) **Construct** a diagram below to depict the four possible normal products of meiosis that would be produced by the F_1 progeny. Show the chromosomes and the allele(s) they carry. Assume the genes are located on different chromosomes and the gene for flower color is on chromosome 1.

   (b) **Predict** the possible phenotypes and their ratios in the offspring of a testcross between an F_1 individual and a *ggdd* individual.

   (c) If the two genes were genetically linked, **describe** how the proportions of phenotypes of the resulting offspring would most likely differ from those of the testcross between an F_1 individual and a *ggdd* individual.

AP BIOLOGY • EXERCISE SHEET

5.4 Non-Mendelian Genetics

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

KEY WORDS incomplete dominance 不完全显性 • codominance 共显性 • sex-linked 伴性 • phenotype 表型 • genotype 基因型

Objective

Build the skills to answer exam questions on **non-Mendelian genetics**.

You must be able to:

- describe **incomplete dominance** 不完全显性 and **codominance** 共显性
- describe **multiple alleles** (e.g. ABO blood groups) and **sex-linked** 伴性 traits
- predict offspring for these patterns

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Incomplete dominance

Neither allele fully dominates, so the heterozygote is a **blend**. Red (RR) × white (WW) flowers give **pink** (RW) — a 1 : 2 : 1 phenotype ratio in the F2.

Codominance

Both alleles are fully expressed together (not blended). In ABO blood, I^AI^B gives type **AB** — both A and B markers appear.

Multiple alleles

A gene can have **more than two** alleles in the population (though each individual has only two). ABO blood group has three: I^A, I^B, i.

Sex-linked traits

Genes on the **X chromosome** (like color blindness) are **sex-linked**: males (XY) show a recessive X trait with just one copy, so they are affected more often.

2 Practice

Now apply the methods above.

2.1 In incomplete dominance, what is the heterozygote's phenotype? [1]

2.2 What blood type is genotype $I^A I^B$, and why? [2]

2.3 Why are males more often affected by X-linked recessive traits? [1]

3 Exam-style questions

3.1 When both alleles are fully expressed in the heterozygote, the pattern is [1]

- **A** complete dominance
- **B** incomplete dominance
- **C** codominance
- **D** recessive

3.2 Red (RR) and white (WW) flowers show incomplete dominance (pink RW).

(a) Cross two pink flowers ($RW \times RW$) and give the phenotype ratio. [3]

(b) State how this differs from a normal Mendelian $3:1$ ratio. [1]

3.3 A color-blind allele is X-linked recessive. Explain why a son can inherit color blindness from a carrier mother. [2]

Solutions

2.1 A blend of the two (e.g. pink).

2.2 Type AB — both the I^A and I^B alleles are fully expressed (codominance).

2.3 Males have only one X chromosome, so a single recessive allele is expressed (no second X to mask it).

3.1 C — codominance.

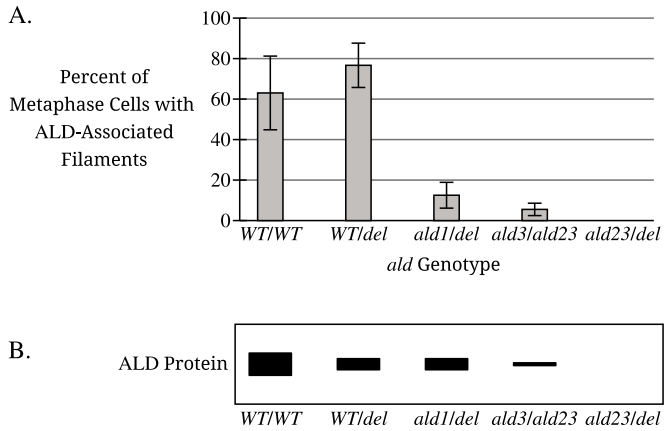
3.2 (a) $RW \times RW$ gives $1\,RR : 2\,RW : 1\,WW = 1$ red : 2 pink : 1 white. (b) The heterozygote (pink) is a distinct phenotype, so there are three phenotypes $(1 : 2 : 1)$ instead of two $(3 : 1)$.

3.3 The mother carries one color-blind X allele; she can pass that X to her son, and since he has only one X (from her), he will be color-blind.

6. The *ald* gene of fruit flies encodes the ALD protein, which is associated with both the centromeres of chromosomes and protein filaments produced during meiosis. In the absence of functional ALD proteins, gamete-producing cells enter anaphase I before homologous chromosomes are correctly aligned. As a result, the gametes produced do not contain the correct numbers of chromosomes.

Scientists generated four mutations in the *ald* gene: *ald1*, *ald3*, *ald23*, and *del*, which was a deletion of the gene. To study the role of the ALD protein in meiosis, scientists used gameteforming metaphase cells from groups of flies with different *ald* genotypes. Some of the flies were homozygous for the wild-type allele of *ald*: *WT/WT*. Other flies were heterozygous for different *ald* alleles: *WT/del*; *ald1/del*; *ald3/ald23*; *ald23/del*. The scientists measured the percent of metaphase cells that contained ALD-associated filaments (Figure 1A) and the amount of ALD protein produced by each of the cell types (Figure 1B).

Figure 1. (A) The average percent of gamete-forming metaphase cells that contained filaments associated with ALD and (B) the amount of ALD protein produced by each cell type. A thicker band indicates a greater amount of ALD protein.



A. Based on Figure 1A, **identify** the fly genotype in which the average percent of metaphase cells with ALD-associated filaments is close to 12%.

B. Based on Figure 1B, **describe** the difference in ALD protein production between gamete-forming metaphase cells of flies with the genotype *ald3/ald23* and flies with the genotype *ald23/del*.

C. Scientists hypothesize that gamete-forming metaphase cells can produce a normal amount of ALD-associated filaments even when they produce about half as much ALD protein as the wild-type cells produce. Use the data in Figures 1A and 1B to **support** the scientists' hypothesis.

D. For gamete-forming metaphase cells of the *WT/del* and *ald1/del* flies, **explain** why the phenotypes observed in Figure 1A differ even though the amount of ALD protein produced (Figure 1B) does not.

STOP

END OF EXAM

2. Elevated levels of CO_2 increase the rate of photosynthesis and growth in plants. Scientists studying the mechanisms involved in these increases examined a variety of species and found that when plants are exposed to elevated levels of CO_2, there is an increase in the number of chloroplasts per cell. To investigate whether the elevated levels of CO_2 have a similar effect on the number of mitochondria in plant cells, the scientists then selected six of these species to quantify the number of mitochondria per cell when the plants were exposed to both normal and elevated levels of CO_2 (Table 1).

TABLE 1. AVERAGE NUMBER OF MITOCHONDRIA IN PLANTS EXPOSED TO NORMAL AND ELEVATED LEVELS OF CO_2

Species	Mitochondria at Normal CO_2 (per 100 μm^2 of cell area) $\pm 2SE_{\bar{x}}$	Mitochondria at Elevated CO_2 (per 100 μm^2 of cell area) $\pm 2SE_{\bar{x}}$
1	1.0 ± 0.10	1.6 ± 0.10
2	0.4 ± 0.05	0.9 ± 0.08
3	0.5 ± 0.07	0.9 ± 0.10
4	0.3 ± 0.03	0.6 ± 0.06
5	0.7 ± 0.06	1.5 ± 0.22
6	1.3 ± 0.15	2.4 ± 0.22

(a) **Describe** the role of the inner mitochondrial membrane in cellular respiration.

(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1. **Determine** which species show(s) a difference in the number of mitochondria between normal and elevated levels of CO_2.

(c) Based on the data in Table 1, **describe** the relationship between the level of CO_2 and the average number of mitochondria per unit area of a cell.

(d) The leaves of a particular plant species are typically green, but scientists notice a plant in which the leaves have white stripes. They determine that the stripes result from a mutation in mitochondrial DNA that interferes with the development of chloroplasts. The scientists crossed plants using pollen from the plant with white-striped leaves and ovules from a plant with green leaves. **Predict** the phenotype(s) of the leaves of offspring produced from this cross. Provide reasoning to **justify** your prediction. **Explain** why plants with the same genotype are able to differ in the structure and/or number of certain organelles in response to changes in atmospheric levels of CO_2.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

2. Geneticists investigated the mode of inheritance of a rare disorder that alters glucose metabolism and first shows symptoms in adulthood. The geneticists studied a family in which some individuals of generations II and III are known to have the disorder. Based on the pedigree (Figure 1), the geneticists concluded that the disorder arose in individual II−2 and was caused by a mutation in mitochondrial DNA.

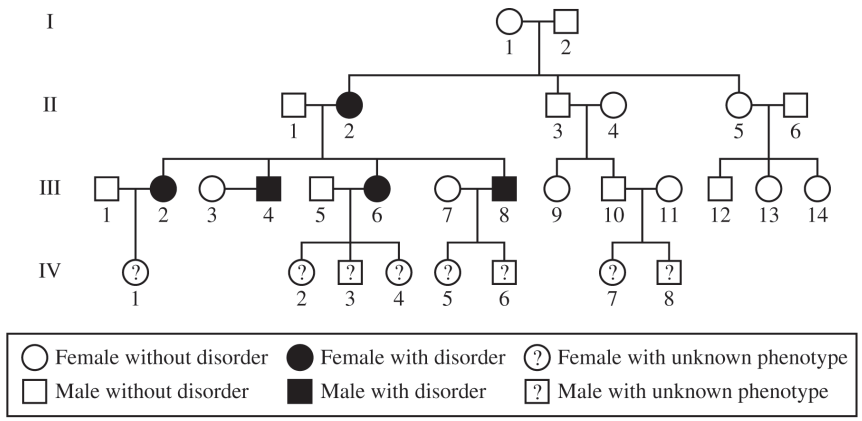


Figure 1. Pedigree of a family showing individuals with the glucose metabolism disorder. A question mark indicates that the phenotype is unknown.

TABLE 1. AVERAGE BLOOD GLUCOSE LEVELS OF INDIVIDUALS IN GENERATION IV

Individual	Average Blood Glucose Level (mg/dL ± $2SE_{\bar{x}}$)
IV−1	170 ± 15
IV−2	190 ± 10
IV−3	145 ± 5
IV−4	165 ± 15
IV−5	110 ± 15
IV−6	125 ± 5
IV−7	105 ± 15
IV−8	120 ± 10

TABLE 2. PHENOTYPIC CLASSIFICATIONS BASED ON BLOOD GLUCOSE LEVELS

Phenotype	Blood Glucose Level (mg/dL)
Normal	< 140 mg/dL
At risk	140 − 199 mg/dL
Affected	≥ 200 mg/dL

(a) The disorder alters glucose metabolism. **Describe** the atoms AND types of bonds in a glucose molecule.

(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph based on the data in Table 1. **Determine** one individual who is both at risk of developing the disorder and has a significantly different blood glucose level from that of individual IV−1.

(c) Based on the pedigree, **identify** all individuals in generation IV who can pass on the mutation to their children.

(d) Based on the fact that individual II−2 is affected, a student claims that the disorder is inherited in an X-linked recessive pattern. Based on the student's claim, **predict** which individuals of generation III will be affected by the disorder. Based on the pedigree, **justify** why the data do NOT support the student's claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

3. The pyruvate dehydrogenase complex (PDC) catalyzes the conversion of pyruvate to acetyl-CoA, a substrate for the Krebs (citric acid) cycle. The rate of pyruvate conversion is greatly reduced in individuals with PDC deficiency, a rare disorder.

   (a) **Identify** the cellular location where PDC is most active.

   (b) **Make a claim** about how PDC deficiency affects the amount of NADH produced by glycolysis AND the amount of NADH produced by the Krebs (citric acid) cycle in a cell. **Provide reasoning** to support your claims based on the position of the PDC-catalyzed reaction in the sequence of the cellular respiration pathway.

   (c) PDC deficiency is caused by mutations in the *PDHA1* gene, which is located on the X chromosome. A male with PDC deficiency and a homozygous female with no family history of PDC deficiency have a male offspring. **Calculate** the probability that the male offspring will have PDC deficiency.

		STRAINS		
	MEDIUM	Wild Type	Mutant 1	Mutant 2
Treatment I	All amino acids present	+	+	+
Treatment II	No amino acids present	+	–	–
Treatment III	All amino acids present EXCEPT methionine	+	–	+
Treatment IV	All amino acids present EXCEPT leucine	+	+	–

Table 1. The data show the growth of haploid *Saccharomyces cerevisiae* yeast strains on media that differ in amino acid content. A plus sign (+) indicates that the yeast strains grow, and a minus sign (–) indicates that the strains do not grow.

6. The yeast *Saccharomyces cerevisiae* is a single-celled organism. Amino acid synthesis in yeast cells occurs through metabolic pathways, and enzymes in the synthesis pathways are encoded by different genes. The synthesis of a particular amino acid can be prevented by mutation of a gene encoding an enzyme in the required pathway.

   A researcher conducted an experiment to determine the ability of yeast to grow on media that differ in amino acid content. Yeast can grow as both haploid and diploid cells. The researcher tested two different haploid yeast strains (Mutant 1 and Mutant 2), each of which has a single recessive mutation, and a haploid wild-type strain. The resulting data are shown in Table 1.

   (a) **Identify** the role of treatment I in the experiment.

   (b) **Provide reasoning** to explain how Mutant 1 can grow on treatment I medium but cannot grow on treatment III medium.

   (c) Yeast mate by fusing two haploid cells to make a diploid cell. In a second experiment, the researcher mates the Mutant 1 and Mutant 2 haploid strains to produce diploid cells. Using the table provided, **predict** whether the diploid cells will grow on each of the four media. Use a plus sign (+) to indicate growth and a minus sign (–) to indicate no growth.

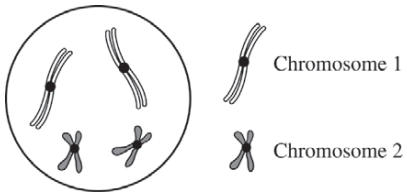
		STRAINS			
	MEDIUM	Wild Type (haploid)	Mutant 1 (haploid)	Mutant 2 (haploid)	Diploid Cells Produced by Mating Mutant 1 and Mutant 2
Treatment I	All amino acids present	+	+	+	
Treatment II	No amino acids present	+	–	–	
Treatment III	All amino acids present EXCEPT methionine	+	–	+	
Treatment IV	All amino acids present EXCEPT leucine	+	+	–	

7. In the tongue sole fish (*Cynoglossus semilaevis*), sex is determined by a combination of genetics and environmental temperature. Genetically male fish have two Z chromosomes (ZZ), and genetically female fish have one Z chromosome and one W chromosome (ZW). When fish are raised at 22°C, ZZ fish develop into phenotypic males and ZW fish develop into phenotypic females. However, when fish are raised at 28°C, the Z chromosome is modified (denoted as Z*). Z*W individuals develop as phenotypic males that are fertile and can pass on the Z* chromosome to their offspring even when the offspring are raised at 22°C. A cross between a ZW female and a Z*Z male is shown in the Punnett square below.

	Z	W
Z*	Z* Z	Z* W
Z	Z Z	Z W

(a) **Predict** the percent of phenotypic males among the F_1 offspring of the cross shown in the Punnett square if the offspring are raised at 22°C.

(b) At least one Z or Z* chromosome is necessary for survival of the fish. A researcher crossed two fish and observed a 2:1 ratio of males to females among the offspring. Based on the information, **identify** the genotype of the male parent in the cross. **Describe** ONE fitness cost to the female of mating with this particular male.

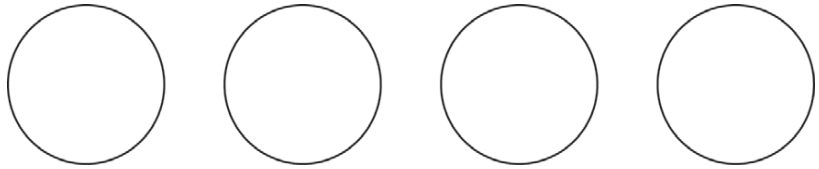


7. In a certain species of plant, the diploid number of chromosomes is 4 (2n = 4). Flower color is controlled by a single gene in which the green allele (*G*) is dominant to the purple allele (*g*). Plant height is controlled by a different gene in which the dwarf allele (*D*) is dominant to the tall allele (*d*). Individuals of the parental (P) generation with the genotypes *GGDD* and *ggdd* were crossed to produce F_1 progeny.

   (a) **Construct** a diagram below to depict the four possible normal products of meiosis that would be produced by the F_1 progeny. Show the chromosomes and the allele(s) they carry. Assume the genes are located on different chromosomes and the gene for flower color is on chromosome 1.

   (b) **Predict** the possible phenotypes and their ratios in the offspring of a testcross between an F_1 individual and a *ggdd* individual.

   (c) If the two genes were genetically linked, **describe** how the proportions of phenotypes of the resulting offspring would most likely differ from those of the testcross between an F_1 individual and a *ggdd* individual.



AP BIOLOGY • EXERCISE SHEET

5.5 Environmental Effects on Phenotype

Name: _____ Class: _____ Date: _____ **Total: 9 marks**

KEY WORDS phenotype 表现型 • genotype 基因型 • codominance 共显性 • meiosis 减数分裂

Objective

Build the skills to answer exam questions on **environmental effects on phenotype**.

You must be able to:

- explain that **phenotype** 表现型 depends on genes **and** environment
- give examples (temperature, diet, sunlight)
- distinguish inherited variation from environmental variation

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Genes plus environment

An organism's **phenotype** is shaped by both its **genotype** and its **environment**. Two individuals with the same genes can look different if raised in different conditions.

Worked examples

- **Hydrangea flower color** depends on soil pH.
- **Human height** depends on genes **and** nutrition (diet).
- **Arctic fox / Himalayan rabbit fur color** changes with temperature.

Environmental variation

Differences caused only by the environment (like a bodybuilder's muscles) are **not inherited** — they are not coded in the DNA passed on.

Distinguishing the two

Ask: would offspring inherit this difference? Genetic differences are heritable; purely environmental differences are not.

2 Practice

Now apply the methods above.

2.1 Phenotype is determined by genotype and what else? [1]

2.2 Give one example of an environmental effect on phenotype. [1]

2.3 Is a suntan an inherited trait? Explain briefly. [1]

3 Exam-style questions

3.1 Two genetically identical plants grown in different light look different. This shows [1]

- **A** a mutation
- **B** an environmental effect on phenotype
- **C** codominance
- **D** meiosis

3.2 Identical twins are raised in different countries and one is much taller.

(a) Explain how twins with the same genes can differ in height. [2]

(b) State whether the height difference would be passed to their children. [1]

3.3 Explain how you could tell whether a difference between two organisms is genetic or environmental. [2]

Solutions

2.1 The environment.

2.2 Any one: hydrangea color and soil pH, height and diet, fur color and temperature.

2.3 No — it is caused by sunlight (environment), not coded in DNA, so it is not inherited.

3.1 B — an environmental effect on phenotype.

3.2 (a) Phenotype depends on genes **and** environment; different diets/nutrition can produce different heights despite identical genes. (b) No — an environmentally-caused difference is not inherited.

3.3 Raise them in the **same** environment: any remaining difference is genetic; a difference that disappears was environmental.

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