Unit 3

Answers: Genetics

Quick checks

1 c The spindle fibers attach to the **kinetochores**, the protein discs on either side of the centromere, and pull the chromatids apart by them. Telomeres are the ends; the satellite and secondary constriction are found on only a few chromosomes.

2 c A J has one long leg and a tiny hook: the centromere is near one end, so the short arm is very short. That is an **acrocentric** chromosome. Equal arms make a V (metacentric), a clearly shorter arm an L (submetacentric), and no short arm at all a straight rod, I (telocentric).

3 b An egg is haploid: it has 23 chromosomes, one from each pair. One of them is a sex chromosome (always an X in an egg), so the autosomes are $23 - 1 = \mathbf{22}$.

4 b Poor food changed his body, not his genes. It is **environmental variation**: his children inherit his genes, not his childhood, so they can grow as tall as their genes and their food allow.

5 b The two homologous chromosomes of a pair carry the **same genes in the same order**, one from each parent. The alleles at a locus may be the same (TT) or different (Tt). The sex chromosomes X and Y are the exception: they share only a few genes.

1 a. **b** The **centromere** (primary constriction) joins the sister chromatids until anaphase, when they are pulled apart.

1 b. **d** Humans have metacentric, submetacentric and acrocentric chromosomes, but **no telocentric** ones; the house mouse's chromosomes are nearly all of that kind.

1 c. **b** **Bateson** named the subject in 1905. Johannsen named the gene (1909); Mendel worked out its first rules; Morgan placed a gene on a chromosome.

1 d. **b** A gene's place is its **locus**. An allele is one form of a gene, and the kinetochore and centromere are parts of the chromosome.

1 e. **b** **Sutton and Boveri** (1902–1903) saw that chromosomes behave as Mendel's factors do. Watson and Crick found DNA's structure (1953); Tjio and Levan counted 46 human chromosomes (1956).

2 a. At metaphase the chromosomes are at their most tightly coiled: short, thick and clearly visible, with the two chromatids, the centromere and the arms easy to see. They also line up in one plane in the middle of the cell, so they can be counted and photographed. In a nucleus that isn't dividing, the chromatin is a fine, tangled network in which single chromosomes can't be told apart.

2 b. Every individual made by sexual reproduction begins as a zygote formed when a sperm and an egg fuse. Each gamete brings one set of chromosomes, one from the father and one from the mother, so the zygote has two sets: each chromosome from one parent has its partner, the homologous chromosome, from the other. Every body cell is made from the zygote by mitosis, which copies the chromosomes exactly, so all body cells have the chromosomes in pairs.

3 i.

Metacentric chromosome	Acrocentric chromosome
The centromere is in the middle.	The centromere is near one end.
The two arms are equal or nearly equal.	One arm is very short, the other very long.
Arm ratio 1 to 1.7.	Arm ratio more than 3.
V-shaped at anaphase.	J-shaped at anaphase.
Example: human chromosome 1.	Example: human chromosome 21, and the Y.

3 ii.

Heredity	Variation
The passing of characters from parents to offspring.	The differences between members of the same species.
Makes offspring resemble their parents.	Makes offspring differ from their parents and from each other.
Example: children of a dark-haired family having dark hair.	Example: brothers of different heights.
Always through genes.	Through genes (hereditary) or the surroundings (environmental).

4 a. A **chromosome** is a thread-like body in the nucleus, made of one long DNA molecule wound on histone proteins, that carries the genes and is seen clearly during cell division.

At metaphase it has two sister chromatids joined at the centromere (primary constriction), with a kinetochore on each side; a short arm (p) and a long arm (q); telomeres at the ends; and on some chromosomes a secondary constriction with a satellite beyond it.

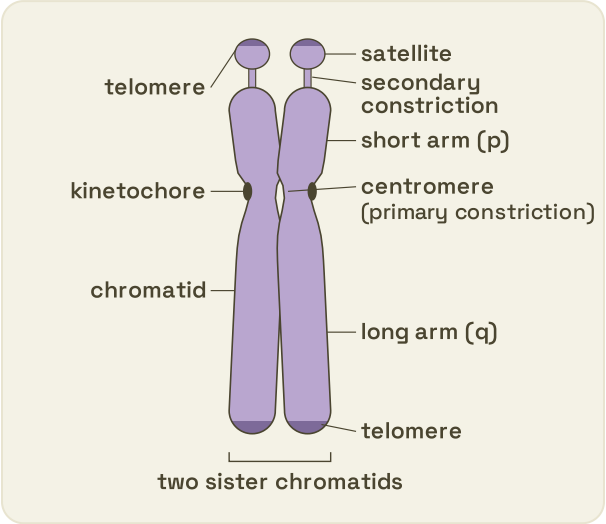


Figure 3.8 *A chromosome at metaphase, with its parts labeled.*

4 b. **Centromere:** holds the sister chromatids together until anaphase; its kinetochores are where the spindle fibers attach, so it leads the chromatid to the pole when the cell divides.

Telomeres: cap and protect the ends of the chromosome, stopping them from fraying and from sticking to the ends of other chromosomes.

Secondary constriction: on some chromosomes, holds the genes for ribosomal RNA, around which the nucleolus forms (the nucleolar organizer); it also separates the satellite from the rest of the arm.

4 c.

a. Metacentric: the centromere in the middle; arms equal; V-shaped at anaphase (human chromosome 1).

b. Submetacentric: the centromere a little off the middle; one arm clearly longer; L-shaped at anaphase (human X chromosome).

c. Acrocentric: the centromere near one end; a very short arm; J-shaped at anaphase (human chromosome 21).

d. Telocentric: the centromere at the very end; only one arm; rod-shaped (I) at anaphase (the house mouse's chromosomes; none in humans).

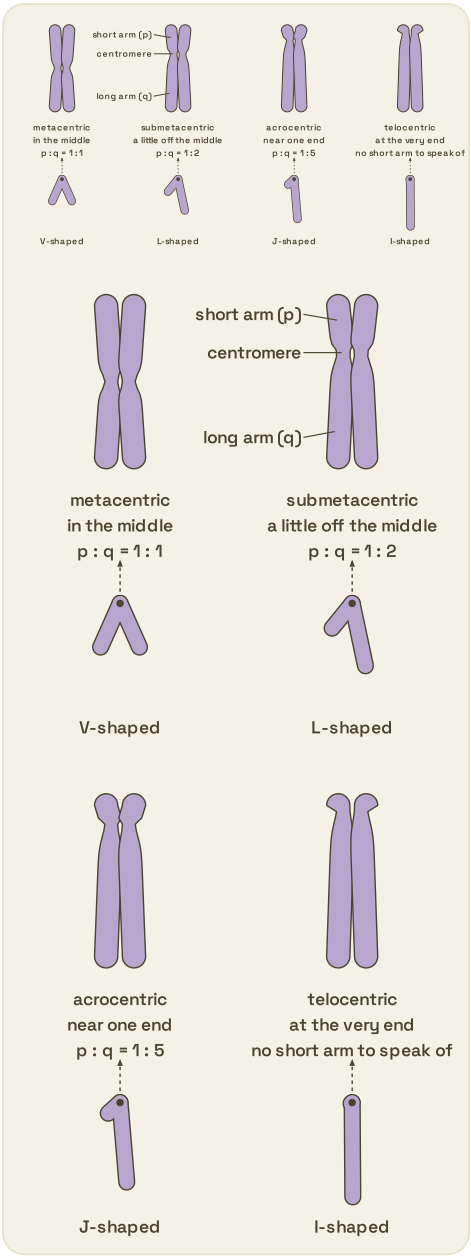


Figure 3.9 *The four types, with their shapes at anaphase.*

4 d.

1. A gene is a segment of the DNA of a chromosome; a chromosome is one long DNA molecule with its proteins.
2. Each chromosome carries many genes (hundreds to thousands), arranged in a line, each at its own fixed place, its locus.
3. Chromosomes come in homologous pairs, one from each parent, and the two of a pair carry the same genes at the same loci, so genes too come in pairs; the two may be the same allele or different ones.
4. When gametes form, the two chromosomes of each pair separate, taking their genes with them, so each gamete gets one gene of each pair; at fertilization the pairs are made again.

4 e. **Chromosome theory of inheritance** (Sutton and Boveri, 1902–1903): genes are carried on chromosomes, and characters are inherited because chromosomes are passed from parents to offspring.

1. Both genes and chromosomes occur in pairs in body cells.
2. The two of each pair separate when gametes are formed, so each gamete has only one of each pair, both of genes and of chromosomes.
3. Different pairs separate independently of one another.
4. In fertilization, one of each pair comes from each parent, so the pairs are made again in the zygote.

5 a.

$$p + 2.5p = 7 \qquad 3.5p = 7\,, \quad p = 2$$

Long arm $q = 2.5 \times 2 = 5$ μm.
The arms are 2 μm and 5 μm. An arm ratio of 2.5 lies between 1.7 and 3, so it is **submetacentric**, L-shaped at anaphase.

5 b. $p = 5.5$ μm, $q = 12 - 5.5 = 6.5$ μm.

$$= \frac{6.5}{5.5} = 1.18$$

Less than 1.7, so it is **metacentric** (the arms are nearly equal), V-shaped at anaphase.

5 c. Autosomes in a body cell $= 78 - 2 =$ **76** (38 pairs).
A sperm is haploid: $78 \div 2 =$ **39** chromosomes, which are 38 autosomes and **one sex chromosome, X or Y**.

5 d. The cell still has **46 chromosomes**. Each has been copied into two sister chromatids held by one centromere, so there are $46 \times 2 =$ **92 chromatids** and **46 centromeres**.