Unit 2

Answers: Life and Life Process

Quick checks

1 c *Rhizobium* in the nodules of beans, peas and lentils fixes nitrogen from the air, which feeds the plant and enriches the soil. Raising batter is a use in food, insulin in medicine and sewage treatment in the environment.

2 c *Mucor* is a fungus, and the study of fungi is mycology. Bacteriology is the study of bacteria, virology of viruses, and immunology of the body's defenses.

3 c Once the phage DNA is inside, its genes take over the cell in the biosynthesis step: an enzyme made by the phage chops up the bacterium's DNA, and the cell's machinery is turned to making phage DNA and proteins.

4 b Only the DNA goes in, down the hollow tail. The protein head, tail and fibers stay outside as an empty coat. This fact, shown by Alfred Hershey and Martha Chase in 1952, helped prove that genes are made of DNA, not protein.

5 c 2 hours is 120 minutes, which is 120 ÷ 30 = 4 generations. $2^4 = 16$. (8 is the trap of counting only 3 doublings; 4 is the number of generations, not of cells.)

6 c In budding, the offspring starts as a small outgrowth and the two cells are unequal. Copying the DNA, identical offspring and being asexual are true of both binary fission and budding.

7 c Everything in *Mucor*'s life is haploid except the zygospore, where the nuclei of + and − gametangia fuse. Its nuclei undergo meiosis when it germinates, so the spores of the germ sporangium are haploid again.

8 b A cross wall forms near the tip of each progametangium: the tip becomes the gametangium and the part behind it the suspensor.

9 c In starters such as *marcha*, molds of the *Mucor* group break down the starch of the grain into sugar, which yeasts then ferment into alcohol: a use, not a harm. The other three are harms it does.

1 a. **c** Mycology comes from the Greek *mykes*, fungus. Phycology is the study of algae.

1 b. **b** The phage must first attach, then inject its DNA; only then can the cell make phage parts (biosynthesis), which are assembled (maturation) before the cell bursts (release).

1 c. **b** The septum is the new cross wall that grows inward from the cell's wall and membrane and cuts the cell in two. A columella is in a sporangium, a capsid is a virus's coat, and a bud scar is left on a yeast cell.

1 d. **b** Baker's yeast reproduces asexually by budding: a small bud grows from the mother cell, gets a nucleus by mitosis and breaks away.

1 e. **c** *Mucor*'s hyphae have no cross walls (aseptate) and contain many nuclei in a continuous cytoplasm: they are coenocytic. Their nuclei are haploid.

1 f. **c** The columella is cut off from the spore-forming part of the sporangium by a dome-shaped wall. It bears no spores.

1 g. **c** *Mucor mucedo* is heterothallic: a gametangium from a + mycelium fuses with one from a − mycelium, and the fused cell becomes the zygospore.

1 h. **c** 1 hour = 60 minutes = 3 generations, and $2^3 = 8$. (3 is the number of generations, and 6 is the trap of adding 2 each time instead of doubling.)

2 a. A virus has no cell, no ribosomes, no enzymes for making energy and no food store. Outside a living cell it can do nothing at all. It can multiply only inside a living host cell, by using the host's ribosomes, enzymes and materials to make copies of itself. Since it can't live and multiply any other way, it is an obligate (compulsory) parasite.

2 b. During biosynthesis, an enzyme made by the phage breaks down the bacterium's own DNA, so the cell can no longer make its own proteins; all its machinery is used to make phage parts. At the end of the cycle, phage proteins make holes in the membrane and lysozyme digests the cell wall, so the cell bursts (lyses) to release the new phages. A cell with no DNA and a burst wall can't live.

2 c. Before the cell divides, its single circular chromosome is copied exactly, and one copy goes into each daughter cell. No genes from any other cell are mixed in, as fission is asexual. So each daughter has the same DNA as the parent and as its sister (apart from a rare copying mistake, a mutation).

2 d. *Mucor*'s hyphae have no cross walls (septa), so a whole branched hypha is one continuous mass of cytoplasm with many nuclei in it, all inside one cell wall. A body of this kind, many nuclei in a shared cytoplasm without dividing walls, is called coenocytic.

2 e. *Mucor* spores, which are always in the air and on surfaces, need moisture, food and warmth to germinate and grow. Bread in a closed box in a warm, damp room has all three, and the box keeps the moisture in, so the spores grow quickly into a mycelium. In a fridge, at about 4 °C, the mold's enzymes work very slowly, so it grows much more slowly (though the cold doesn't kill it).

2 f. The zygospore has a thick, tough, dark, warty wall that protects it from drying out, cold and damage. It can rest for months, through conditions that kill the thin-walled mycelium, and germinates only when moisture and food are available again. So the mold survives bad times in the form of zygospores.

3 i.

Binary fission	Budding
Seen in prokaryotes such as *E. coli* (and some protists).	Seen in yeast (and in *Hydra*, among animals).
The parent cell splits across the middle into two.	A small outgrowth (bud) forms on one side of the parent.
The two daughter cells are equal in size.	The bud is smaller than the mother cell.
The parent cell no longer exists: it becomes the two daughters.	The mother cell lives on and can bud again, keeping a bud scar each time.
In bacteria, the DNA is copied and pulled apart without a spindle.	The nucleus divides by mitosis, one nucleus going into the bud.

3 ii.

Sporangiospore	Zygospore
Formed asexually, inside a sporangium.	Formed sexually, by the fusion of two gametangia.
Haploid (n).	Diploid (2n).
Small, thin-walled and light, made in thousands.	Large, single, with a thick, black, warty wall.
Spreads the mold quickly by wind.	Survives bad conditions, resting for months.
Germinates into a new mycelium directly.	Undergoes meiosis on germination, giving a germ sporangium.
Offspring are copies of the parent.	Offspring are new combinations of two strains' genes.

3 iii.

Gametangium	Suspensor
The end (tip) part of a progametangium, cut off by a cross wall.	The stalk part of the progametangium, behind the cross wall.
Fuses with a gametangium of the other strain.	Doesn't fuse.
Its contents become part of the zygospore.	Holds up the zygospore and is left empty.

3 iv.

Asexual reproduction	Sexual reproduction
Takes place when there is plenty of food.	Usually takes place when food runs short or two strains meet.
Needs only one mycelium.	Needs a + and a − mycelium.
By sporangiospores, formed in sporangia on sporangiophores.	By conjugation of gametangia, forming a zygospore.
No fusion of nuclei; no meiosis.	Nuclei fuse, then meiosis on germination.
Many offspring, quickly; all copies of the parent.	Few offspring; new combinations of genes.

4 a. **Microbiology** is the branch of biology that studies microorganisms: living things too small to see clearly without a microscope, together with viruses. It studies their structure, life processes, reproduction and their effects on people, animals, plants and the environment.
Its branches, based on the microbes studied, are: **bacteriology** (bacteria), **virology** (viruses), **mycology** (fungi), **protozoology** (protozoa) and **phycology** (algae).

4 b.

1. **Medicine:** it finds the microbes that cause diseases and how they spread, and gives us antibiotics, vaccines and medicines such as insulin made by bacteria.
2. **Agriculture:** it studies useful soil microbes such as nitrogen-fixing *Rhizobium* and the decomposers that make compost, and the microbes that cause crop and animal diseases.
3. **Food:** it explains how microbes make *dahi*, *gundruk*, *kinema*, bread and *jaand*, and why food spoils and how to preserve it.
4. **Industry:** microbes are used to make alcohol, vinegar, enzymes, vitamins and many medicines.
5. **Environment:** it explains how decomposers recycle nutrients, and uses microbes to treat sewage and make biogas.

4 c. The lytic cycle is the way a virulent bacteriophage, such as T4, multiplies inside a bacterium such as *E. coli*, ending with the bacterium bursting.

1. **Attachment (adsorption):** the phage's tail fibers bind to particular receptor molecules on the bacterium's surface, and its baseplate settles on the cell wall.
2. **Penetration:** the tail sheath contracts and pushes the hollow tail tube through the cell wall, after lysozyme at its tip makes a hole. The phage DNA passes down the tail into the cell; the empty protein coat stays outside.
3. **Biosynthesis:** the phage DNA takes control of the cell. The host's DNA is broken down, and the cell's ribosomes, enzymes and materials make many copies of the phage DNA and the phage's proteins (heads, tails, fibers).
4. **Maturation (assembly):** the parts assemble into complete new phages, each head filled with a copy of the DNA.
5. **Release (lysis):** phage enzymes weaken the cell membrane and wall; the bacterium bursts, releasing about 100–150 new phages, which infect other bacteria.

For T4 at 37 °C, the cycle takes about 25–30 minutes.
(Diagram: a bacterium drawn five times in a ring, showing a phage attached by its tail fibers; its DNA entering; phage DNA and parts inside, host DNA in pieces; complete phages inside; the cell burst with phages escaping. Label: phage, tail fibers, phage DNA, host DNA, new phages, cell wall.)

4 d. *E. coli* is a rod-shaped bacterium, a prokaryote with a single circular chromosome and no nucleus. It reproduces asexually by binary fission:

1. **DNA replication:** the circular chromosome is copied, giving two identical chromosomes.
2. **Elongation:** the cell grows longer, and the two chromosomes are carried apart towards opposite ends.
3. **Septum formation:** a ring of protein forms round the middle of the cell, and the cell membrane and wall grow inward there, forming a cross wall, the septum.
4. **Division:** the septum closes completely, and the cell splits into two equal daughter cells, each with one chromosome and its share of the cytoplasm and ribosomes.

The daughters are genetically identical to the parent. In good conditions this happens about every 20 minutes.
(Diagram: four stages of a rod-shaped cell: one nucleoid; two nucleoids in a longer cell; a septum growing in at the middle; two separate cells. Label: cell wall, cell membrane, DNA, septum, daughter cells.)

4 e. Yeast is a unicellular fungus. In budding:

1. A small outgrowth, the **bud**, appears on one side of the mother cell, and cytoplasm flows into it.
2. The nucleus moves to the neck between the mother and the bud and divides by mitosis; one daughter nucleus passes into the bud.
3. The bud grows, taking in cytoplasm, mitochondria and part of the vacuole.
4. A wall forms across the neck, and the bud separates as a new yeast cell, leaving a **bud scar** on the mother.

Sometimes the buds don't separate and bud again, forming a chain of cells called a **pseudomycelium**.
(Diagram: an oval yeast cell with a nucleus and vacuole; the same cell with a small bud and the nucleus in the neck; a larger bud with one nucleus in each cell; a separated bud and the mother with a scar; a chain of four cells.)

4 f. *Mucor* reproduces asexually mainly by **sporangiospores**:

1. Some hyphae grow upward as **sporangiophores**.
2. The tip of each swells into a round **sporangium**, into which cytoplasm and many nuclei flow.
3. A dome-shaped wall separates the sterile central **columella** from the outer part, where the cytoplasm divides into many small, walled, haploid **sporangiospores**.
4. When ripe, the sporangium turns black and its wall bursts, leaving a collar at the columella's base. The light spores are carried by wind.
5. On a moist, food-rich surface, each spore germinates into a new mycelium.

Mucor can also reproduce asexually by thick-walled **chlamydospores** formed in the hyphae, and vegetatively by **fragmentation** of the mycelium.

4 g. *Mucor mucedo* is heterothallic: sexual reproduction happens only between a + and a − mycelium. It takes place by conjugation, usually when food runs short.

1. Hyphae of the two strains grow side branches, **zygophores**, towards each other, attracted by hormones, until their tips touch.
2. The tips swell into multinucleate **progametangia**.
3. A cross wall divides each progametangium into a terminal **gametangium** and a stalk, the **suspensor**.
4. The wall between the two gametangia dissolves; their cytoplasm mixes and + and − nuclei pair and fuse, forming diploid nuclei.
5. The fused cell develops into a **zygospore** with a thick, black, warty wall, held between the two suspensors. It rests through bad conditions.
6. On germination, the diploid nuclei undergo **meiosis**; the zygospore cracks and puts out a **germ sporangiophore** with a **germ sporangium** at its tip, full of haploid spores, each of which grows into a + or a − mycelium.

(Diagrams: two hyphae with touching progametangia; gametangia cut off by cross walls, with suspensors; a warty zygospore between two suspensors; a germinating zygospore with its germ sporangium.)

4 h. The life cycle has two loops that share the haploid mycelium:

- **Asexual loop:** mycelium (n) → sporangiophore with sporangium → sporangiospores (n) released → spores germinate → mycelium.
- **Sexual loop:** + and − mycelia (n) → zygophores and progametangia → gametangia and suspensors → fusion → zygospore (2n) → meiosis on germination → germ sporangium with spores (n) → new mycelia, each + or −.

Only the zygospore is diploid; every other stage is haploid.
(Diagram: as in the life cycle widget above, with the mycelium in the middle, the asexual loop on one side and the sexual loop on the other, each stage drawn and labeled, and the zygospore marked 2n.)

4 i. **Advantages:**

1. It decomposes dead plant and animal matter, recycling nutrients into the soil.
2. Molds of its group help ferment starters such as *marcha* and foods such as *sufu*, breaking starch into sugar.
3. It is used to make enzymes, such as microbial rennet for cheese, and some species can ferment plant waste into alcohol.

Disadvantages:

1. It spoils bread, roti, fruits, vegetables, jam and stored grain.
2. Some species cause mucormycosis, a dangerous infection in people with weak immunity, such as uncontrolled diabetics.
3. Its spores cause allergies and asthma, and some species rot fruits in storage.

4 j. A virus has no cell, so it can't split. Binary fission is a cell growing and dividing in two, and needs the cell's own machinery to copy its DNA and build new wall. A virus has no ribosomes or enzymes of its own and does nothing at all outside a host. It multiplies only by getting its genetic material into a living host cell, which then makes many new viruses at once (in the lytic cycle, about 100 or more from one bacterium) and is destroyed. Also, whether a virus is "living" at all is debated: it shows signs of life only inside a host cell.

5 a.

$$n = \frac{4 \times 60}{20} = 12$$
$$N = N_0 \times 2^{\,n} = 1 \times 2^{12} = 4{,}096$$

4,096 cells.

5 b.

$$n = \frac{180}{30} = 6, \qquad N = 500 \times 2^6 = 500 \times 64 = 32{,}000$$

32,000 bacteria.

5 c. $$\frac{N}{N_0} = \frac{64{,}000}{1{,}000} = 64 = 2^6$$

So it doubled 6 times in 120 minutes.

$$= \frac{120}{6} = 20$$

20 minutes.

5 d. $2^n = 1{,}024 = 2^{10}$, so $n = 10$ generations.
Time $= 10 \times 25 = 250$ minutes $=$ **4 hours 10 minutes**.

5 e. 1 hour $=$ 2 cycles of 30 minutes.
After cycle 1: 150 phages; 1 bacterium killed.
After cycle 2: $150 \times 150 =$ **22,500 phages**; 150 more bacteria killed.
Bacteria killed in all $= 1 + 150 =$ **151**.

5 f. From 7 a.m. to 3 p.m. is 8 hours, which is $n = \frac{8}{2} = 4$ generations.

$$N = 50{,}000 \times 2^4 = 50{,}000 \times 16 = 800{,}000$$

800,000 yeast cells.

5 g. *E. coli*: $n = \frac{200}{20} = 10$, so $N = 2^{10} = 1{,}024$.
Yeast: $n = \frac{200}{100} = 2$, so $N = 2^2 = 4$.
1,024 bacteria and 4 yeast cells: $\frac{1{,}024}{4} = 256$ times more bacteria.

5 h. In each hour there are $60 \div 20 = 3$ generations. After 1 hour, $N = N_0 \times 2^3 = 8N_0$; after 2 hours, $N = N_0 \times 2^6 = 64N_0$.
So after 2 hours there are $\frac{64}{8} =$ **8 times** as many, not 2 times. Each extra hour multiplies the bacteria by 8, which is why food left out spoils so much faster than people expect.