Unit 5

Answers: Applied Biology

Quick checks

1 b The dead, keratin-filled surface layer is the body's main wall against germs. Where it is burned away, the moist, living tissue underneath is open to bacteria, so infection is one of the biggest dangers after a serious burn (losing water is another).

2 b The cilia beat toward the throat, so the mucus blanket, with the dust and germs stuck in it, travels up and away from the delicate air sacs of the lungs. In the throat it is swallowed (stomach acid kills most of the germs) or coughed out.

3 c When the pseudopodia close round the bacterium, it ends up in a bag made of the cell's own membrane: the phagosome. Lysosomes then join it (a phagolysosome) and pour in their enzymes. The arms are pseudopodia; the waste is thrown out by exocytosis.

4 c B lymphocytes that recognize an antigen multiply, and most of them become plasma cells, which make and release the antibodies. Neutrophils and macrophages eat germs; red blood cells carry oxygen.

5 b With two binding sites, each antibody can link two germs, and many antibodies glue many germs together into clumps: agglutination. (The clumping of red cells when blood groups are mixed is the same thing.)

6 c That is herd immunity. Measles needs a chain of people who can catch it. If more than about 93% of the people around the baby are immune, an infected person passes it to fewer than one other on average, the chain breaks, and the virus never reaches her.

7 b Penicillin blocks the building of the bacterial cell wall, a structure our cells simply don't have, so it attacks the bacteria and leaves our cells alone.

8 b The resistance was already there, by chance, in a few bacteria. The antibiotic doesn't cause it; it removes their competitors. The survivors multiply and pass the resistance on, so with every use the resistant share grows.

1 a. **c** The first line is the barriers at the surface: skin, mucous membranes and their mucus, tears, saliva, stomach acid. Neutrophils belong to the second line; antibodies and memory cells to the third.

1 b. **b** Cilia on the ciliated cells of the windpipe and bronchi beat toward the throat. Villi line the small intestine; flagella are long whips that move some bacteria and sperm; pseudopodia are the arms of a phagocyte.

1 c. **a** Neutrophils make up about 40 to 70% of the white cells and reach an infection within hours, where they eat bacteria and die, forming pus.

1 d. **b** The baby receives ready-made antibodies (passive) in a natural way, through breast milk and, before birth, across the placenta (natural). It fades in months, since the baby makes no memory cells from it.

1 e. **c** The tetanus vaccine contains the tetanus toxin made harmless by chemicals: a toxoid. BCG, oral polio and MR are live, weakened vaccines.

1 f. **b** Alexander Fleming noticed that a *Penicillium* mold killed the bacteria round it. Jenner tested the smallpox vaccine (1796), Metchnikoff discovered phagocytes (1882), and Waksman's laboratory found streptomycin (1943).

2 a. Tobacco smoke slows and, over time, destroys the cilia of the windpipe and bronchi. The mucus is then no longer swept up to the throat: it collects in the airways, and the only way to clear it is to cough (the smoker's cough). Germs trapped in the mucus stay in the airways and multiply there, causing bronchitis and pneumonia more often.

2 b. Neutrophils rush to the infected wound in large numbers and eat the bacteria by phagocytosis. Each neutrophil dies after eating a few bacteria. The dead neutrophils, together with the dead bacteria, broken tissue and fluid from the leaky capillaries, collect as thick, yellowish pus.

2 c. A vaccine prevents the disease, so the child never suffers it, nor its dangers (death, blindness, paralysis) or the cost of treatment and lost school and work. Many diseases that vaccines prevent, such as measles and polio, are caused by viruses for which there is no cure. Vaccination also protects people who can't be vaccinated, through herd immunity, and it reduces the use of antibiotics and so the spread of resistance.

3 i.

Innate immunity	Acquired immunity
Present from birth.	Gained during life, after meeting a germ or a vaccine.
Non-specific: works against all germs alike.	Specific: aimed at one particular germ.
Acts at once.	Takes days to develop the first time.
No memory; no faster the second time.	Has memory cells; faster and stronger the second time.
Skin, mucous membranes, phagocytes, inflammation, fever.	Lymphocytes and antibodies.

3 ii.

Active immunity	Passive immunity
The body produces antibodies itself, after meeting the antigen.	The body receives antibodies already made by another person or an animal.
Protection builds up slowly, over one to two weeks.	Protection begins as soon as the antibodies arrive.
Memory cells form, so it lasts for years, sometimes for life.	No memory cells form; the antibodies are broken down within weeks or months.
Example: after recovering from measles, or after the MR vaccine.	Example: a baby's antibodies from its mother, or antivenom after a snakebite.
Prevents disease in the future.	Gives quick, short protection when there is no time to wait.

3 iii.

Vaccine	Antibiotic
A dead or weakened germ, a part of it, or a toxoid.	A chemical made by a microbe, or on its pattern, that kills or stops bacteria.
Given to healthy people to **prevent** a disease.	Given to sick people to **cure** a bacterial infection.
Works by making the body produce antibodies and memory cells (active immunity).	Acts on the bacteria directly.
Exists against bacteria and viruses.	Acts only on bacteria, not viruses.
Protection lasts for years.	Acts only while it is being taken.

3 iv.

Primary response	Secondary response
At the first meeting with an antigen.	At a later meeting with the same antigen.
Slow: antibodies appear after several days.	Fast: antibodies rise within a day or two.
Antibody level rises only a little.	Antibody level rises much higher.
Antibodies fall again fairly soon.	Antibodies stay high for much longer.
The person usually falls ill.	The person usually doesn't fall ill.

4 a. The skin is the body's first line of defense:

1. **Physical barrier:** its outer layer is many layers of dead, flattened cells filled with keratin, tightly packed, which most germs can't pass through.
2. **Shedding:** the surface cells flake off all the time, taking germs with them.
3. **Dryness:** most bacteria can't multiply on its fairly dry surface.
4. **Acid and chemicals:** sweat and sebum keep the surface slightly acid (about pH 5), and some fatty acids of sebum and proteins in sweat kill bacteria and fungi.
5. **Friendly bacteria:** harmless bacteria living on the skin use up space and food and keep harmful ones from settling.

When the skin is cut, burned or bitten, germs can get in, so wounds must be cleaned and covered.

4 b.

- **In the nose,** hairs stop large particles, and the sticky mucus on the walls of the twisting nasal passages traps most dust and germs; a sneeze blows them out.
- **In the windpipe and bronchi,** the lining is a ciliated epithelium with goblet cells. The **goblet cells** make mucus, which traps dust and germs and contains lysozyme and antibodies (IgA) that kill or stop them. The **cilia** beat in waves toward the throat and carry the mucus blanket upwards (the mucociliary escalator).
- **In the throat,** the mucus is swallowed, and stomach acid kills the germs; or it is coughed out.

Diagram: draw the tall ciliated cells side by side on a basement membrane, each with its nucleus and cilia on top; one or two goblet cells among them, swollen with mucus that opens at the top; a layer of watery liquid round the cilia and a blanket of mucus over them with dots of dust and bacteria; and an arrow along the mucus pointing up, "toward the throat". Label: cilia, mucus, goblet cell, ciliated cell, nucleus, trapped dust and bacteria, basement membrane (as in Figure 5.2).

4 c. **Phagocytosis** is the process by which certain white blood cells (phagocytes: neutrophils and macrophages) take in germs, dead cells and other particles, enclose them in a bag of membrane and digest them. Its steps:

1. **Chemotaxis:** the phagocyte senses chemicals released by the bacteria and damaged tissue and moves toward them.
2. **Adherence:** it attaches to the bacterium, most easily when the bacterium is coated with antibodies.
3. **Ingestion:** it surrounds the bacterium with pseudopodia, which meet and fuse, enclosing it in a phagosome inside the cell.
4. **Digestion:** lysosomes fuse with the phagosome to form a phagolysosome, whose enzymes kill and digest the bacterium.
5. **Release:** the undigested remains are thrown out of the cell by exocytosis.

4 d. An **antibody** (immunoglobulin) is a Y-shaped protein, made of two heavy and two light chains, that binds one particular antigen at the tips of its two arms.

Production: a germ's antigen is recognized by the B lymphocytes whose antibodies fit it, with the help of helper T cells. These B cells multiply into a clone. Most become plasma cells, which release large numbers of antibodies into the blood; some become memory cells, which remember the antigen for years.

How they act: they **neutralize** viruses and toxins by covering the parts that do harm; they **agglutinate** germs into clumps, since each antibody has two binding sites; they **coat** germs so that phagocytes eat them more easily; and they switch on **complement**, blood proteins that burst bacteria.

4 e. **Immunity** is the body's ability to resist a disease by preventing the germ's entry or destroying it or its toxin before it causes illness. Acquired immunity is gained during life, and is of four kinds:

- **Natural active:** the body makes its own antibodies after catching a disease and recovering. Example: immunity to chickenpox after having it.
- **Artificial active:** the body makes its own antibodies after a vaccine. Example: immunity to measles after the MR vaccine.
- **Natural passive:** ready-made antibodies pass from mother to baby across the placenta and in breast milk. Example: a newborn's protection in the first months.
- **Artificial passive:** ready-made antibodies are injected. Example: antivenom after a snakebite, rabies immunoglobulin after a dog bite.

Active immunity is slow to develop but lasts long; passive immunity acts at once but fades in weeks to months.

4 f. **Vaccination** is the giving of a vaccine (a dead or weakened germ, a part of it, or a toxoid) by injection or by mouth, so that the body makes antibodies and memory cells against that germ without suffering the disease: artificial active immunity.
Importance:

1. It protects the vaccinated person from serious diseases.
2. It gives herd immunity: when most people are immune, the disease can't spread, so babies and others who can't be vaccinated are protected too.
3. It can eradicate a disease, as it did smallpox in 1980, and nearly polio.
4. It is far cheaper than treatment, and saves children from death and disability.
5. It reduces the use of antibiotics, and so antibiotic resistance.

Four vaccines in Nepal's program: BCG (tuberculosis); pentavalent (diphtheria, whooping cough, tetanus, hepatitis B and Hib); MR (measles and rubella); OPV and fIPV (polio); also PCV (pneumonia and meningitis from pneumococcus), rotavirus (diarrhea), JE (Japanese encephalitis), TCV (typhoid), HPV (cervical cancer). Any four.

4 g. **Antibiotics** are chemical substances produced by microorganisms (bacteria or fungi), or made in laboratories on the same pattern, that kill bacteria or stop their growth without seriously harming the patient. Examples: penicillin (from *Penicillium*), streptomycin (from *Streptomyces*).
Advantages:

1. They cure bacterial diseases such as pneumonia, typhoid, cholera and tuberculosis.
2. They prevent and treat infections after surgery, childbirth and injuries, making modern medicine possible.
3. They stop the spread of bacterial diseases by curing the patients who carry them.
4. They have saved millions of lives and raised life expectancy.

Disadvantages:

1. They kill the friendly bacteria of the gut, causing diarrhea and fungal infections.
2. They can cause side effects (hearing damage, stained teeth) and allergic reactions, sometimes dangerous.
3. They have no effect on viral diseases.
4. Their misuse and overuse make bacteria resistant, so that infections become hard or impossible to treat.

4 h. **Antibiotic resistance** is the ability of bacteria to survive an antibiotic that once killed them, so that the antibiotic no longer cures the infection.
How it develops: among a large number of bacteria, a few, by chance mutations, can survive the antibiotic. When it is used, the others are killed and these survive and multiply, so the resistant ones take over. Bacteria can also pass resistance genes to each other on plasmids. Every use of an antibiotic, especially unnecessary or careless use, favors the resistant ones.
Slowing it down:

1. Use antibiotics only when prescribed by a doctor, never for colds and flu.
2. Take them exactly as prescribed, without stopping early on your own.
3. Never share them or keep leftovers; don't buy them without a prescription.
4. Don't use them to make healthy farm animals grow faster.
5. Prevent infections by hand-washing, clean water, hygiene in hospitals and vaccination.

5 a. Share needed $= 1 - 1 \div 10 = 1 - 0.1 = 0.9$, that is 90%.
Students who must be immune $= 0.9 \times 800 =$ **720 students**.
If more than 720 of the 800 are immune (from having had chickenpox or from the vaccine), each case passes it on to fewer than one other student on average, and the outbreak dies out. (A real school isn't perfectly mixed, so this is a rough figure.)

5 b. Tetanus bacteria in the soil and dung on the nail can enter the wound and release a toxin that acts within days. Pemba has not been vaccinated recently, so his body has no antibodies ready.

- The **anti-tetanus serum** gives **artificial passive immunity**: ready-made antibodies that neutralize the toxin at once, but last only a few weeks.
- The **vaccine** (a toxoid) gives **artificial active immunity**: his own body starts making antibodies and memory cells, which takes one to two weeks but then lasts for years, after the rest of the doses.

So the serum protects him now, and the vaccine protects him later, after the serum has faded.

5 c. The pharmacist should tell him that a runny nose and sore throat are almost always caused by a cold virus, that antibiotics don't act on viruses, and that his body will usually clear the infection in about a week; rest, fluids and warm drinks help. An antibiotic would do nothing to the virus, but could cause side effects (diarrhea, allergy) and would kill the sensitive bacteria living in his body, leaving resistant ones to multiply, so that an antibiotic might fail him later when he really needs it. If he has a high fever, difficulty breathing, or isn't better after several days, he should see a doctor, who can tell whether a bacterial infection needs treatment.

5 d. No.

1. No vaccine protects everyone perfectly: two doses of MR protect about 97 in 100 people against measles. If measles spreads among unvaccinated children, Simran could still be among the few who catch it. When nearly everyone is vaccinated, measles can't spread at all, which protects her too.
2. Her baby brother or sister, an elderly neighbor, or a sick classmate may be unable to be vaccinated or may not respond well. They are protected only by herd immunity, which needs more than about 93% of people to be immune to measles. Each child who isn't vaccinated weakens that protection for everyone.