Key terms

Pathogen: living thing or virus that causes disease.

Non-specific (innate): same for every germ; ready from birth.

Specific: aimed at one germ; has memory.

Mucociliary escalator: cilia move the mucus blanket up to the throat.

Inflammation: red, hot, swollen, painful; histamine.

Phagocytosis: phagocytes take in germs, enclose and digest them.

Antigen: foreign molecule that starts an immune response.

Antibody (immunoglobulin): Y-shaped protein, made by B cells, binds one antigen.

Immunity: ability to resist a disease.

Vaccine: dead or weakened germ, its part, or inactivated toxin; makes antibodies and memory cells, no disease.

Toxoid: toxin made harmless.

Herd immunity: the unvaccinated protected by the immunity around them.

Cold chain: 2 to 8 °C from factory to arm.

Antibiotic: from a microbe, or on its pattern; kills or stops bacteria.

Bactericidal / bacteriostatic: kills (penicillin) / stops multiplying (tetracycline).

Broad / narrow spectrum: many kinds (tetracycline) / a few (penicillin).

Antibiotic resistance: bacteria survive a drug that once killed them.

Formula

$$\text{share immune} = 1 - \frac{1}{R_0}$$

R_0: people one case infects, on average, where nobody is immune
Use: herd immunity

- measles, $R_0 = 15$: about 93%
- $R_0 = 4$: 75%
- polio, $R_0 \approx 6$: about 83%
- chickenpox, $R_0 \approx 10$, 800 students: $0.9 \times 800 = 720$
- one survivor, 30 min a division, 10 h: 20 divisions, $2^{20} \approx$ a million

5.1 Skin and mucous membrane

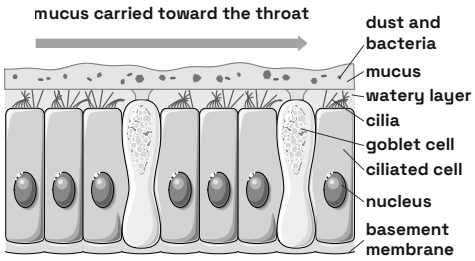
Line	What	Examples	Against
first	surface barriers	skin, mucus, cilia, tears, saliva, stomach acid	all germs
second	attack what gets in	phagocytes, inflammation, fever	all germs
third	recognize, remember	lymphocytes, antibodies	one germ

Skin (1.5–2 m^2; epidermis, keratin)

- tough barrier of dead cells, 15–20 layers
- shedding carries germs away
- dry surface
- acid, about pH 5 (sweat, sebum)
- friendly bacteria use the space and food
- works only while unbroken

Mucous membrane (at every opening; *mucus* is the liquid)

- **goblet cells** make mucus
- traps dust and germs; holds lysozyme and IgA
- nose
  - hairs
  - sneeze
  - twisting passages
- windpipe and bronchi
  - ciliated epithelium
  - 12–15 beats a second
  - about 200 cilia a cell
  - 0.5–1 cm a minute, up
- throat: swallowed (acid kills) or coughed out
- damage
  - tobacco
  - cold dry air
  - wood and dung smoke
  - flu and cold viruses
- others
  - tears, saliva (lysozyme)
  - stomach acid, about pH 2
  - urine
  - friendly bacteria
- Fleming found lysozyme, 1921



The ciliated lining of the windpipe.

5.2 Blood in defense

- white cells
  - 4,000–11,000 per μL
  - nucleus
  - squeeze out of capillaries
- **inflammation**
  - histamine widens vessels (red, hot)
  - leaky walls (swelling)
  - pain
  - neutrophils arrive
- **pus**
  - dead neutrophils
  - bacteria
  - tissue
- **fever**: slows many germs, speeds white cells

Neutrophils	Macrophages (from monocytes)
most common, first to arrive	live in tissues for months
a few bacteria, then die	about a hundred; clear debris
main cells in pus	show germ pieces to lymphocytes

Phagocytosis

1. **chemotaxis**: moves toward chemicals
2. **adherence**: attaches; antibodies are handles
3. **ingestion**: pseudopodia → **phagosome**
4. **digestion**: lysosomes → **phagolysosome**
5. **release**: exocytosis

Metchnikoff: starfish larvae, thorns, 1882; Nobel 1908 with Ehrlich.

Lymphocytes (made in bone marrow)

- **B cells**: make antibodies
- **T cells** (mature in the thymus)
  - **helper** direct
  - **killer** kill infected cells
  - HIV destroys helpers

Antibody: 2 heavy + 2 light chains in a Y; 2 antigen-binding sites.

Production: recognition (helper T) → multiplying (clone) → **plasma cells** pour out antibodies → **memory cells** remain. About a week the first time.

Action

- **neutralization**: covers a virus's or toxin's active part
- **agglutination**: clumps (two arms)
- **marking** (opsonization): eaten faster
- **bursting**: switches on complement

5.3 Immunity and vaccination

- innate
  - from birth
  - all germs
  - at once
  - no memory
- acquired: specific, memory

	Active	Passive
natural	after a disease	placenta, milk, colostrum
artificial	vaccine	antivenom, rabies immunoglobulin, anti-tetanus serum

Active	Passive
own B cells	antibodies given
1–2 weeks	at once
memory; years or life	no memory; weeks to months
prevents	immediate protection

Primary	Secondary
first meeting	later meeting
several days' delay	a day or two
rises a little	tens to hundreds of times higher
falls soon; ill	stays high; usually not ill

Vaccine kind	Examples
live, weakened	BCG, OPV, MR, rotavirus, JE
killed	fIPV
toxoid	tetanus, diphtheria
subunit, conjugate	hepatitis B, Hib, PCV, TCV, HPV
mRNA	some COVID-19 vaccines

- Jenner, 14 May 1796: cowpox, James Phipps; *vacca*, cow

- smallpox declared eradicated, 1980; WHO's South-East Asia Region free of polio, 2014
- why
  - protects the person
  - herd immunity
  - can wipe out a disease
  - saves money
  - fewer antibiotics
- colds: 200+ viruses; flu changes its antigens yearly

Nepal's schedule (2026; began 1979; 14 diseases, free)

Age	Vaccines
birth	BCG
6, 10 weeks	pentavalent, OPV, PCV, rotavirus
14 weeks	pentavalent, OPV, fIPV
9 months	MR, PCV, fIPV
12 months	JE
15 months	MR, TCV
Grade 6 girls	HPV
pregnant women	Td

5.4 Antibiotics

- Fleming, *Penicillium*, 1928
- Florey, Chain, Heatley, 1940–41
- Nobel 1945
- word in this sense: Waksman, 1940s

Antibiotic	From	Against
penicillin	*Penicillium*	throat, pneumonia, wounds
cephalosporins	*Acremonium*	chest, skin, urinary
streptomycin	*Streptomyces griseus*	tuberculosis
tetracycline	*Streptomyces*	cholera, acne
erythromycin	*Saccharopolyspora*	whooping cough

How they work

- cell wall: penicillin, cephalosporins; a growing bacterium bursts
- 70S ribosomes (ours 80S)
  - streptomycin
  - tetracycline
  - erythromycin
- DNA copying: ciprofloxacin
- viruses have none of these: colds, flu, measles, COVID-19 untouched

Advantages	Disadvantages
cure bacterial diseases	kill friendly bacteria: diarrhea, thrush
make surgery possible	side effects: hearing, stained teeth
stop some spreading	allergy, anaphylaxis
saved millions	resistance

Resistance

- a few resistant by chance (mutation)
- drug kills the rest
- they multiply
- plasmids pass genes on
- 1.14 million deaths in 2021 (2024 study); over 39 million forecast, 2025–2050
- worse
  - colds
  - no prescription
  - skipping
  - sharing
  - healthy farm animals
  - poor hygiene
- do
  - only when prescribed
  - exactly as prescribed
  - never share
  - prevent infections
- exam: "complete the full course prescribed by the doctor; don't stop it early on your own"

Vaccine	Antibiotic
prevents, in healthy people	cures, in sick people
active immunity	acts on bacteria directly
bacteria and viruses	bacteria only
lasts years	only while taken

COMMON MISTAKES

✗ antigen and antibody swapped
✓ antigen is foreign; antibody is the body's.

✗ mucus membrane
✓ mucous membrane; mucus is the liquid.

✗ the antibiotic causes resistance
✓ it kills the others; resistance was there.

✗ antibiotics for a cold
✓ viruses; no effect.

✗ passive immunity makes memory cells
✓ none; it fades.

✗ share immune $= 1 \div R_0$
✓ $1 - 1 \div R_0$.

✗ all phagocytes die after a few bacteria
✓ neutrophils do; macrophages live for months.