Test 1 Terms

398 entries. Names, jobs and connections.

Find a category

The basic pieces	2
Innate cells: recognise, swallow, kill	3
Adaptive cells: B cells and T cells	5
Tissues, supporting cells and compartments	7
Antigen recognition and display	10
CD markers and receptor partnerships	11
Cytokines: inflammation and recruitment	14
Cytokines: helper programmes and brakes	15
Interferons and blood-cell growth signals	16
Antibodies: classes and subclasses	17
Antibody structure and complexes	19
Complement: tag, recruit, perforate	20
Danger sensors and signalling complexes	23
Killing molecules and soluble defence proteins	26
Microbial structures and danger molecules	28
Laboratory targets, reagents and readouts	30
Clinical connections and wording traps	32

Repeated names are combined. Includes wrong-option names and connecting terms. Memory cues are reminders, not complete definitions. The reference does not alter the quizzes' source answer keys.

Connect the pieces

Recruit neutrophils

Microbial pattern → **macrophage** / DC → **IL-1** + TNF activate vessels; **CXCL8** attracts neutrophils; **G-CSF** increases production.

Activate a naive T cell

Peptide-**MHC** + **TCR**/**CD4** or **CD8** → recognition. B7 + **CD28** → costimulation. **CD3** relays; **IL-2** supports expansion.

Help a B cell

BCR binds **antigen** → B-**cell** **MHC II** presents **peptide** → helper T-**cell** recognition → **CD40L** + **CD40** and cytokines → **antibody** response.

Kill a swallowed microbe

IgG / **C3b** / **iC3b** coat → **phagocyte** attaches → **phagosome** + **lysosome** → **NADPH oxidase** / **ROS** and enzymes kill.

Build inflammatory signals

NLRP3 + **ASC** + **procaspase-1** → active **caspase-1** → mature **IL-1 beta** / **IL-18**. **TLR** signalling separately changes gene transcription.

Use complement

Classical / lectin / alternative → C3 cleavage → **C3b** tags; **C3a** promotes inflammation. **C5a** recruits; **C5b**-9 forms a pore.

Sources: three Test 1 decks (316 cards); Janeway, Immunobiology, NCBI Bookshelf (innate responses, complement, T-cell activation); MedlinePlus Genetics (CGD). Detailed source links are on the online page.

01 The basic pieces

Cell = worker. Receptor = receiver. Cytokine = message. Antibody = target-binding protein.

Cell

A basic living unit of the body, enclosed by a membrane. Different cell types have different jobs; immune cells are specialised cells that help protect the body.

CONNECT Cells make molecules; a **cytokine** such as **IL-6** is not a cell.

Protein

A molecule made from a folded chain of amino acids. Its shape allows it to do a job, such as binding a target, carrying a message or speeding up a chemical reaction.

CONNECT Includes antibodies, cytokines, most receptors and enzymes.

Amino acid

Small molecules that join together to build peptides and proteins. Their order and chemical properties help determine how the resulting protein folds and works.

CONNECT Amino acids join into peptides and longer **protein** chains.

Peptide / polypeptide

A peptide is a chain of amino acids; polypeptide usually means a longer chain. The order of the amino acids and the folded shape determine interactions. A peptide is not necessarily a complete protein.

CONNECT **MHC** displays peptide fragments; antibodies themselves are folded polypeptide chains.

Glycoprotein

A protein with sugar chains attached. Antibodies are glycoproteins; their attached sugars can influence how they interact with immune cells and other defence proteins.

CONNECT Antibodies and many surface receptors are proteins with attached sugars.

DNA

Deoxyribonucleic acid: the molecule that stores genetic instructions. A gene is a stretch of DNA; the order of its chemical building blocks is its sequence.

CONNECT B- and T-**cell** DNA contains **receptor** genes; antigens do not encode the antibodies against them.

RNA

Ribonucleic acid: a molecule involved in using genetic instructions, including messages used to make proteins. Some viruses also use RNA as their genetic material.

CONNECT Helps cells use **DNA** instructions. Viral **double-stranded RNA** can also be a danger clue.

01 The basic pieces (continued)

Gene / V(D)J segments

A gene is a section of DNA with instructions for a functional product. V, D and J mean variable, diversity and joining segments. Developing lymphocytes join different segments to make antigen receptors; D segments are used only in certain receptor chains.

CONNECT Rearranged gene segments build diverse **BCR** and **TCR** variable regions.

Remember Rearrange first; B cells can fine-tune later.

Enzyme

A biological catalyst, usually a protein, that speeds up a chemical reaction without being used up. In an immunoassay, an attached enzyme can turn a substrate into a coloured or light-producing product.

CONNECT Examples: **lysozyme**, **caspase-1** and **NADPH oxidase**; enzymes can also **label** an immunoassay.

Receptor / ligand

A receptor is a protein or protein complex that recognises a particular partner and often starts a signal. Ligand means the molecule that binds it. A cytokine is a signal; its receptor is the receiving molecule.

CONNECT A receptor receives a binding partner, its ligand. **CD40L** is the ligand for **CD40**.

Antigen

A molecule or molecular feature that can be specifically recognised by an antibody or antigen receptor. It may come from a microbe or from the body itself; antigen does not automatically mean harmful or able to trigger a response alone.

CONNECT **BCR** or **antibody** binds directly; conventional **TCR** recognises **peptide** together with **MHC**.

Epitope / antigenic determinant

The particular small part of an antigen that a receptor recognises. Antibodies bind an accessible feature directly; most T cells recognise a peptide fragment together with its MHC holder.

CONNECT An **antigen** can contain many epitopes. CDR loops form the **antibody** surface that recognises one.

Linear / conformational epitope

A linear epitope depends on a continuous amino-acid sequence. A conformational epitope depends on a folded shape that may bring distant parts of a sequence together. Unfolding a protein can destroy conformational epitopes.

CONNECT Conventional T cells recognise presented peptides; antibodies can recognise either kind.

01 The basic pieces (continued)

Native antigen

Conformation means three-dimensional shape. A native antigen retains its natural structure rather than being unfolded or broken into fragments; B-cell receptors and antibodies can recognise such intact features.

CONNECT **BCR** can recognise this directly; no obligatory **APC** or **MHC** display.

Immunogen

An antigen that can induce an immune response. Foreignness, size, chemical complexity, processing and the person's immune system influence this ability, called immunogenicity.

CONNECT All immunogens are antigens, but binding an **antibody** does not guarantee an immune response.

Adjuvant

A substance added to a vaccine to strengthen the immune response to its antigen. Many adjuvants stimulate early innate warning signals, making antigen-presenting cells better at helping activate B and T cells.

CONNECT Vaccine **antigen** + stronger innate activation → more effective adaptive response.

Superantigen

A microbial protein that can activate unusually many T cells by linking MHC II to particular TCR regions. Activation is not limited to the usual matching peptide-specific T-cell clones; excessive cytokine release can result.

CONNECT Bridges **MHC II** and certain **TCR** regions outside normal **peptide**-specific recognition.

02 Innate cells: recognise, swallow, kill

Neutrophil = rapid arrival. Macrophage = swallow and coordinate. Dendritic cell = introduce antigen to naive T cells.

Leukocyte

A white blood cell involved in defence and immune regulation. Leukocyte is a broad category, not one specific cell type. Red blood cells are not leukocytes.

CONNECT Umbrella group containing granulocytes, monocytes and lymphocytes.

Granulocyte

A white blood cell with small storage packets, or granules, visible inside it. Neutrophils, eosinophils and basophils are granulocytes; their granules contain substances used in defence or inflammation.

CONNECT **Neutrophil**, **eosinophil** and **basophil**; their roles are different.

02 Innate cells: recognise, swallow, kill (continued)

Phagocyte

A cell specialised in swallowing particles, microbes or dead cells. Neutrophils, monocytes and macrophages can do this. Calling a cell phagocytic means it can carry out this swallowing process.

CONNECT **IgG** and **C3b** coat a target → phagocyte receptors attach → swallowing.

Neutrophil

A very common white blood cell that rapidly reaches inflamed tissue. It swallows and kills microbes, especially bacteria and fungi; dead neutrophils are a major part of pus.

CONNECT **G-CSF** makes more; **CXCL8** recruits; phagosomes and **NADPH oxidase** help kill.

Monocyte

A white blood cell circulating in blood. It can enter tissues and develop into macrophages or related cells that help remove microbes and damaged material.

CONNECT Blood → tissue recruitment → **macrophage**-like cells. Monocytes ARE phagocytic.

Macrophage

A large immune cell in tissues that swallows microbes, dead cells and debris. It also releases signals, helps repair tissue and can present antigen to helper T cells.

CONNECT **IFN-gamma** boosts killing. Makes **IL-1**, **IL-6**, TNF and other signals; presents **peptide** on **MHC II**.

Dendritic cell (DC)

An immune cell that collects material in tissues and displays fragments of it to T cells. It can travel to a lymph node and is especially good at starting a new T-cell response.

CONNECT Tissue **antigen** → **lymph node** → **peptide**-**MHC** + B7 → **naive** T-**cell** activation.

Langerhans cell

Immune cells in the outer layer of skin that collect material and can present antigen to T cells. They are usually taught as specialised dendritic cells, though they share developmental features with tissue macrophages.

CONNECT Skin sentinel and **antigen** presenter. Often taught with dendritic cells; not a simple ordinary **macrophage**.

Kupffer cell

Resident macrophages in the liver. They help remove microbes, particles and damaged material from blood passing through the liver.

CONNECT Liver-resident **macrophage**; removes material arriving in the liver.

02 Innate cells: recognise, swallow, kill (continued)

Microglial cell / microglia

The resident macrophage-like immune cells of the brain and spinal cord. They monitor their surroundings and remove damaged cells and debris.

CONNECT Resident immune surveillance and debris clearance in the brain and spinal cord.

Osteoclast

A large bone-resorbing cell related to the monocyte/macrophage lineage. It breaks down bone during normal remodelling; it is not a bone-building osteoblast.

CONNECT Myeloid-lineage, bone-resorbing **cell**; appears in the tissue-**macrophage** question.

Mast cell

An immune cell stationed in tissues, especially near body surfaces. It can rapidly release histamine and other stored substances, contributing to immediate allergic reactions.

CONNECT **IgE** on **Fc receptors** → allergen cross-linking → granule release, including **histamine**.

Basophil

A rare blood granulocyte that can release histamine and type-2 cytokines. It expresses high-affinity IgE receptors and participates in allergy and parasite responses. Mast cells are a distinct, mainly tissue-resident cell type.

CONNECT Related to type-2 / **IgE** responses; not a **mast cell** circulating in disguise.

Eosinophil

A white blood cell that releases toxic granule contents against large parasites such as worms. It also contributes to some allergic diseases.

CONNECT **IL-5** promotes eosinophils; granule contents damage parasites and can damage allergic tissues.

Natural killer (NK) cell

Natural killer cell: an innate immune cell that can kill stressed, infected or cancerous cells. It uses a balance of activating and inhibitory signals rather than a rearranged, antigen-specific T-cell receptor.

CONNECT **IL-12** promotes **IFN-gamma** output; **CD16** detects **IgG**-coated targets; **perforin** supports killing.

Remember NK: no prior matching TCR needed.

02 Innate cells: recognise, swallow, kill (continued)

Innate lymphoid cell (ILC)

Immune cells that resemble lymphocytes and rapidly release cytokines, especially in tissues. Unlike B and T cells, they do not have rearranged antigen-specific receptors. Different ILC groups perform different jobs.

CONNECT **ILC1** / **ILC2** / **ILC3** parallel **Th1** / **Th2** / **Th17** functions, without rearranged **antigen** receptors.

ILC1

Group 1 innate lymphoid cells. They make interferon gamma and support defence against intracellular pathogens, broadly paralleling the cytokine programme of Th1 cells. They are not the same cells as Th1 cells.

CONNECT **IFN-gamma** → **macrophage** activation → intracellular-pathogen defence.

ILC2

Group 2 innate lymphoid cells. Their main cytokines include IL-5 and IL-13; they help with worm defence and tissue repair and contribute to allergy, broadly paralleling Th2 responses.

CONNECT **IL-5** → eosinophils; **IL-13** → mucus / barrier response → worm defence and allergy.

ILC3

Group 3 innate lymphoid cells. They make cytokines such as IL-17 and IL-22 that protect barriers against extracellular bacteria and fungi, broadly paralleling parts of Th17 responses.

CONNECT **IL-17** → **neutrophil** recruitment; **IL-22** → epithelial defence → bacteria / **fungi**.

M1 macrophage

An inflammatory macrophage activation pattern associated with microbe killing. M1 is a useful teaching shorthand, not a permanently separate cell lineage.

CONNECT **IFN-gamma** and microbial signals can favour this pattern; real tissue macrophages span a spectrum.

M2 macrophage

A shorthand for several macrophage activation patterns associated with repair and regulation. It does not mean every M2-labelled cell is beneficial in every disease.

CONNECT **IL-4** / **IL-13** can favour one M2-like programme; compare inflammatory M1 responses.

02 Innate cells: recognise, swallow, kill (continued)

Classical, intermediate and non-classical monocytes

Blood-monocyte subsets distinguished by surface markers. Classical cells have high CD14 and little CD16; intermediate cells have high CD14 and CD16; non-classical cells have lower CD14 and high CD16.

CONNECT The exercise figure groups **CD16**-positive cells; that is not a single uniform subset.

Dermal dendritic cell

An antigen-sampling dendritic cell in the skin layer below the epidermis. It can carry antigen to a draining lymph node.

CONNECT Distinct from epidermal **Langerhans cells**; both participate in skin immune surveillance.

03 Adaptive cells: B cells and T cells

B cells make antibodies. Helper T cells give instructions. Cytotoxic T cells kill selected target cells.

Lymphocyte

A group of white blood cells that includes B cells, T cells and natural killer cells. B and T cells provide targeted adaptive immunity; natural killer cells belong to innate immunity.

CONNECT B and T cells are adaptive; NK cells and other ILCs are innate lymphocytes.

Lymphocyte precursor

An earlier, developing cell that will give rise to a more mature cell type. A lymphocyte precursor is not yet a fully functioning mature B or T cell.

CONNECT **Bone marrow** origin; B-**cell** development stays mainly there, T-**cell** development moves to **thymus**.

Naive B / T cell

A mature lymphocyte that has not yet been activated by its matching antigen. It is ready to respond but is not yet an antigen-experienced effector or memory cell.

CONNECT Mature but not yet activated by its **antigen**. Naive is not the same as immature.

B cell

An immune cell that develops in bone marrow and can recognise antigen directly using its surface antibody. After activation it can form antibody-secreting plasma cells or memory B cells.

CONNECT **BCR** binds **native antigen**; **CD19/CD20** identify many B cells; can present **peptide** on **MHC II**.

03 Adaptive cells: B cells and T cells (continued)

B-lymphoblast

A large, immature or activated lymphocyte that is multiplying. B-lymphoblast means a cell in the B-cell family; T-lymphoblast means one in the T-cell family. A mature plasma cell is the specialised antibody-secreting cell.

CONNECT An activated, growing **B cell**; not yet synonymous with a mature **antibody** factory.

Plasma cell

A B cell specialised in making and releasing large amounts of antibody. It is a living cell, not blood plasma, which is the liquid part of blood.

CONNECT Differentiated **B cell** → large-scale **antibody** secretion; usually loses **CD20**.

Memory B cell

A long-lived, antigen-experienced B cell. It is poised to respond again; it is not the same as a long-lived plasma cell continuously secreting antibodies.

CONNECT On repeat exposure, can rapidly expand and produce new **antibody**-secreting cells.

T cell

An immune cell that matures in the thymus. Most T cells recognise a peptide displayed on MHC: helper T cells coordinate responses, while cytotoxic T cells can kill infected or abnormal cells.

CONNECT **TCR** recognises a target; **CD3** transmits the signal; **thymus** provides developmental selection.

Alpha-beta T cell

The most common type of T cell. Its T-cell receptor consists of two protein chains called alpha and beta; conventional CD4 helper and CD8 cytotoxic T cells belong to this group.

CONNECT Includes conventional **CD4** helper and **CD8** cytotoxic cells.

T-lymphoblast

A large, immature or activated lymphocyte that is multiplying. B-lymphoblast means a cell in the B-cell family; T-lymphoblast means one in the T-cell family. A mature plasma cell is the specialised antibody-secreting cell.

CONNECT Activated **T cell** multiplying before or while developing an effector programme.

Effector T cell

An activated cell now carrying out its defence job. An effector helper T cell sends signals; an effector cytotoxic T cell can kill target cells.

CONNECT Already activated: helper cells signal; cytotoxic cells kill.

03 Adaptive cells: B cells and T cells (continued)

CD4 helper T cell / Th

Helper T lymphocytes, usually CD4-positive, coordinate other immune cells using signals and direct contact. Different helper groups support macrophages, antibody production or defence at body surfaces. They do not themselves make antibodies.

CONNECT **CD4** pairs with **MHC II**; helper subsets differ in cytokines and jobs.

Th0

T-helper type 0: a teaching label for a CD4 T cell that has not yet developed a polarised helper programme such as Th1 or Th2. It is not a separate permanent cell lineage.

CONNECT Can develop a specialised helper programme according to surrounding signals.

Th1 / type I helper cell

T-helper type 1, a specialised CD4 T-cell group. It produces interferon gamma and helps macrophages deal with microbes living inside cells.

CONNECT **IL-12** favours Th1 → **IFN-gamma** → **macrophage** activation.

Remember Th1: problems inside cells.

Th2 / type II helper cell

T-helper type 2, a specialised CD4 T-cell group. It produces signals such as IL-4, IL-5 and IL-13, supporting responses to parasitic worms and contributing to allergy.

CONNECT **IL-4**, **IL-5**, **IL-13** → **IgE**, eosinophils and mucus.

Remember Th2: worms and allergy; not type II interferon.

Th17

A specialised helper T-cell group named for IL-17. Its signals help recruit neutrophils and protect body surfaces against extracellular bacteria and fungi.

CONNECT **IL-17** and often **IL-22** → neutrophils and barrier defence against **fungi** / bacteria.

Regulatory T cell / Treg

T cells that act as brakes on immune responses and help prevent attacks on healthy self tissues. Many express CD4 and high amounts of CD25 and can use suppressive signals such as TGF-beta and IL-10.

CONNECT High **CD25** helps use **IL-2**; **IL-10**, **TGF-beta** and contact mechanisms restrain responses.

Remember Treg: the brake, not another attacker.

03 Adaptive cells: B cells and T cells (continued)

CD8 cytotoxic T cell / CTL / Tc

A T cell able to kill infected or abnormal body cells. Conventional CD8 cytotoxic T cells recognise their matching peptide on MHC I and trigger the target cell's death.

CONNECT **TCR** + **CD3** + **CD8**; matching **peptide**-**MHC I** → target-**cell** death.

Memory T cell

An antigen-experienced T cell that persists after the main response. Memory CD4 and CD8 cells can provide faster helper or cytotoxic responses when the target returns.

CONNECT Retains **antigen** experience and can respond more rapidly on re-exposure.

Natural killer T (NKT) cell

Natural killer T cells: a specialised group of T cells, distinct from ordinary NK cells. Many recognise fatty or sugar-fat molecules displayed by CD1d and rapidly release cytokines.

CONNECT Many recognise lipids on CD1d. NKT is a T-**cell** group; ordinary NK cells are different.

Professional APC

A cell that shows peptide fragments on MHC to T cells. Dendritic cells, macrophages and B cells are professional APCs; dendritic cells are especially effective at starting responses in naive T cells.

CONNECT **Dendritic cell**, **macrophage**, **B cell**. Dendritic cells are best at priming **naive** T cells.

B-cell / T-cell clone

A group descended from one B or T cell, initially sharing its antigen specificity. Expansion produces more matching cells. Activated B-cell descendants can later accumulate antibody-gene mutations.

CONNECT An **antigen** selects existing matching clones; it does not design their receptors.

Type III helper cell / Th3 wording

The decks use Th3 or type III helper cells as distractors in the pregnancy question. Th3 is also a historical label for some TGF-beta-producing regulatory responses, not a standard third member of a simple Th1/Th2/Th3 sequence.

CONNECT Do not substitute this **label** for **Th17**. Learn the actual subset named in the question.

03 Adaptive cells: B cells and T cells (continued)

Haematopoietic stem cell

A self-renewing bone-marrow cell that can give rise to the different blood-cell families.

CONNECT Myeloid and lymphoid progenitors are more restricted descendants.

Remember Stem = source; progenitor = narrower possibilities.

Myeloid progenitor / myeloblast

A myeloid progenitor is a developing cell committed towards myeloid blood-cell types. A myeloblast is an immature precursor on the granulocyte developmental route.

CONNECT Not mature defenders: development produces cells such as neutrophils and monocytes.

Lymphoid progenitor

A developing blood-cell precursor with potential to produce lymphoid cells, including B, T and NK cells.

CONNECT B / T development generates **antigen**-specific receptors; NK development does not generate a **TCR**.

T follicular helper cell / Tfh

A specialised CD4 T cell that helps B cells in follicles and germinal centres produce effective antibodies and memory.

CONNECT **CXCR5** helps position it; ICOS, **CD40L** and **IL-21** support B-**cell** help.

TEMRA cell

An antigen-experienced effector-memory T cell that re-expresses the CD45RA marker. It often has strong immediate effector functions.

CONNECT Memory T-**cell** subtype in the exercise diagram; **CD45RA** does not always mean **naive**.

Intraepithelial lymphocyte / IEL

A lymphocyte located between epithelial cells at a barrier such as the intestine. Many are specialised T cells.

CONNECT Works near epithelial and **M cells**; IEL describes a location, not one single **receptor** type.

Double-negative / double-positive thymocyte

A developing T cell in the thymus. Double-negative means neither CD4 nor CD8 is expressed; double-positive means both are expressed.

CONNECT Selection normally produces a mature single-positive **CD4** or **CD8 T cell**.

04 Tissues, supporting cells and compartments

Bone marrow / thymus = develop. Lymph nodes / spleen / MALT = meet antigen and respond.

Bone marrow

The soft tissue inside bones where blood cells are produced. B cells develop there; T-cell precursors arise there but move to the thymus to mature.

CONNECT Makes blood cells; B cells develop here; **G-CSF** increases **neutrophil** output.

Thymus

An organ in the upper chest where developing T cells mature and are tested. Cells need useful recognition of self MHC without dangerously strong recognition of self antigens.

CONNECT T-**cell** development and selection; severe malnutrition can cause thymic atrophy.

Lymph node

Small organs that filter fluid draining from tissues. They bring antigen-presenting cells, B cells and T cells together so that immune responses can begin.

CONNECT Receives tissue drainage; dendritic cells bring **antigen**; **naive** lymphocytes enter via HEVs.

Spleen

An organ that filters blood, removes ageing red blood cells and supports immune responses to material carried in the bloodstream.

CONNECT Responds to blood-borne antigens; not part of **MALT**.

MALT

Mucosa-associated lymphoid tissue: immune-cell collections at moist body surfaces. Examples include tonsils and Peyer's patches. They help monitor material entering through the mouth, airways and intestine.

CONNECT Mucosa-associated lymphoid tissue: **tonsils**, **appendix**, **Peyer's patches** and dispersed mucosal immune tissue.

GALT

Gut-associated lymphoid tissue: immune tissue associated with the intestine. Peyer's patches are one example. It is a part of the broader mucosal immune system, MALT.

CONNECT Gut-associated lymphoid tissue: the intestinal part of MALT.

04 Tissues, supporting cells and compartments (continued)

Peyer's patches

Groups of immune tissue in the small-intestinal wall. They help immune cells inspect material from the gut and organise responses while tolerating harmless food and many normal microbes.

CONNECT **M cells** move intestinal samples to immune cells beneath them.

Tonsils

Collections of immune tissue near the back of the mouth and throat. They help sample material entering through the mouth and nose and are part of mucosa-associated lymphoid tissue.

CONNECT Sample material at the entrance to the respiratory / digestive tracts.

Appendix

A narrow pouch connected to the first part of the large intestine. Its wall contains immune tissue that forms part of the gut-associated immune system.

CONNECT Contains gut-associated lymphoid tissue.

Diffuse lymphoid tissue

Immune cells spread through a tissue rather than forming one clearly bounded organ or large cluster. Such cells are found throughout many mucosal linings.

CONNECT Distributed immune cells **complement** organised structures such as **Peyer's patches**.

Germinal centre

A temporary area inside an activated lymphoid follicle, such as in a lymph node. B cells multiply and are selected there, producing better-binding antibodies and generating memory B cells or plasma cells.

CONNECT Activated B cells undergo selection and **antibody** affinity improvement here.

Epithelial cell / mucosa

Epithelium is a sheet of cells covering a surface or lining an organ. It forms a physical barrier, and many epithelial cells also release protective substances or signals.

CONNECT Barrier cells receive **IL-22**; mucosal surfaces use **secretory IgA** and local regulation.

04 Tissues, supporting cells and compartments (continued)

M cell / microfold cell

Microfold cells: specialised cells in the intestinal lining over immune tissue such as Peyer's patches. They carry samples from the gut's hollow interior across the lining to immune cells underneath.

CONNECT Gut lumen → transcytosis across M **cell** → underlying APCs.

Remember M = move samples.

Paneth cell

A specialised cell in the lining of the small intestine that releases antimicrobial substances such as defensins. It is an epithelial barrier cell, not a macrophage.

CONNECT Intestinal epithelial **cell** that releases **defensins** and **lysozyme**; NOT a **macrophage**.

Endothelial cell

The endothelium is the layer of cells lining blood vessels. Activation makes these cells display adhesion molecules and signals that help white blood cells attach and pass into inflamed tissue.

CONNECT **IL-1** / TNF activate vessel lining → immune-**cell** attachment and tissue entry.

Postcapillary venule

Small blood vessels immediately after capillaries, the smallest exchange vessels. Many white blood cells leave the circulation through their walls to reach inflamed tissue.

CONNECT Main small-vessel exit site for leukocytes entering inflamed tissue.

HEV

Specialised small veins lined by plump cells that help lymphocytes leave blood and enter lymph nodes or similar immune tissues. HEV is not a name for every vessel through which inflammatory cells leave blood.

CONNECT High endothelial venule: specialised **lymphocyte** entrance into lymphoid tissue; not all venules are HEVs.

Hepatocyte / liver

The liver is an organ that processes substances and makes many blood proteins. Hepatocytes are its main working cells; during inflammation they increase production of proteins such as CRP and fibrinogen.

CONNECT **IL-6** → liver → **CRP**, **fibrinogen** and other **acute-phase proteins**.

04 Tissues, supporting cells and compartments (continued)

Erythrocyte / red blood cell

A red blood cell, whose main job is carrying oxygen using haemoglobin. Its surface antigens determine blood groups; antibodies against those antigens can cause red cells to clump.

CONNECT **EPO** promotes production. Mature human erythrocytes lack nuclei and conventional **MHC I** expression.

Neuron

A neuron is a nerve cell that receives and sends information. Neural means relating to nerves. Neurons are not usual NK-cell targets, but the source's statement should not be taken as an absolute rule for every disease setting.

CONNECT Normally not an NK target; neural signalling can use **acetylcholine** rather than cytokines.

Infected / stressed / tumour cell

A body cell altered by infection, stress or malignant growth. CTLs need their matching peptide-MHC I; NK cells respond to a balance of activating and inhibitory signals, including MHC I. Neither label means every such cell is automatically killed.

CONNECT Can be recognised by CTLs or NK cells; healthy self cells should be spared.

Placenta

An organ that forms during pregnancy and allows exchange between maternal and fetal blood supplies without simply mixing them. IgG antibodies can cross it and give the baby temporary immune protection.

CONNECT Transfers maternal **IgG**, not ordinary **IgM**; gives the fetus temporary **antibody** protection.

Nucleus / cytosol

The nucleus contains most cellular DNA. Cytosol is the fluid inside the cell outside membrane-bound compartments. These are locations, not immune-cell types.

CONNECT Cytosolic **protein** fragments often enter the **MHC I** route.

Phagosome

A membrane-bound compartment containing material that a cell has swallowed. It can join with lysosomes so their destructive contents reach the swallowed microbe.

CONNECT Swallowing encloses a microbe → phagosome fuses with **lysosome**.

04 Tissues, supporting cells and compartments (continued)

Lysosome / phagolysosome

A lysosome is an intracellular compartment containing digestive enzymes. When it fuses with a microbe-containing phagosome, the resulting phagolysosome helps kill and digest the contents.

CONNECT Fusion provides a degradative compartment; **lysozyme** is an **enzyme**, not this **organelle**.

Endoplasmic reticulum / ER

An internal membrane network involved in making and processing proteins. It is the peptide-loading location for the conventional MHC I pathway.

CONNECT **TAP** transports peptides into the ER, where they can be loaded onto **MHC I**.

Blood plasma / serum

The liquid part of blood before clotting, containing water, salts and proteins including antibodies and fibrinogen. It is not the same thing as a plasma cell, which is an antibody-producing cell.

CONNECT Plasma contains **fibrinogen**. Serum is collected after clotting and lacks the **fibrinogen** used in the clot.

Remember Plasma is fluid; a plasma cell is a cell.

Follicular dendritic cell / FDC / FoDC

A non-blood-cell stromal cell in a B-cell follicle that retains intact antigen and immune complexes for B cells to inspect.

CONNECT Unlike conventional dendritic cells, its main role is not **peptide** presentation to **naive** T cells.

Thymic epithelial cell

A supporting cell in the thymus that displays self material and helps developing T cells pass selection.

CONNECT Cortical cells help positive selection; medullary cells help establish tolerance to self.

Goblet cell

An epithelial cell that secretes mucins, the main gel-forming proteins in mucus.

CONNECT Mucus forms a protective barrier; **secretory IgA** works within this barrier.

Absorptive enterocyte

An intestinal epithelial cell specialised for absorbing nutrients and helping maintain the gut barrier.

CONNECT Not a **Paneth cell** or an M **cell**: neighbouring **epithelial cells** have different jobs.

04 Tissues, supporting cells and compartments (continued)

Adenoid / bronchus-associated lymphoid tissue

The adenoid is lymphoid tissue behind the nose. Bronchus-associated lymphoid tissue is immune tissue associated with the airways.

CONNECT Both relate to mucosal defence; the adenoid is the pharyngeal tonsil.

Interfollicular region / IFR

The area between B-cell follicles in lymphoid tissue; it contains many T cells and antigen-presenting cells.

CONNECT Contrasts with the B-**cell**-rich follicle and its **germinal centre**.

Mitochondrion

An internal cell compartment that helps convert nutrients into usable energy and participates in cell signalling and death pathways.

CONNECT Exercise figures mention mitochondrial metabolism; **ATP** is a major energy-transfer **molecule**.

05 Antigen recognition and display

BCR: whole target. TCR: peptide + MHC. CD4 x II = 8; CD8 x I = 8.

BCR

An antibody anchored in the B-cell membrane, together with signalling proteins. It binds antigen directly in its existing form; the antigen does not need to be displayed on MHC.

CONNECT Membrane immunoglobulin + signalling partners; binds **native antigen** without obligatory **MHC**.

TCR

The target-recognition protein on a T cell. Most T-cell receptors recognise a combination of a particular peptide and the MHC molecule holding it, not a free whole virus.

CONNECT Recognises the **peptide**-**MHC** combination; works with **CD3** and **CD4** or **CD8**.

Pre-BCR / pre-TCR

A temporary receptor used while a B or T cell is developing. It tests whether the first successfully made receptor chain works before the cell finishes building its complete antigen receptor.

CONNECT Developmental **receptor**-**chain** checkpoint; not activation by a foreign **antigen**.

05 Antigen recognition and display (continued)

Peptide-MHC complex

A short protein fragment sitting in an MHC binding groove. The peptide is the sample; MHC is its display holder. Conventional T cells recognise the combined surface, not the free peptide alone.

CONNECT **TCR** contacts both partners; incompatible donor **MHC** can prevent antiviral recognition.

MHC / HLA

Major histocompatibility complex: genes encoding proteins that display small protein fragments on a cell's surface for T cells to inspect. MHC I works with CD8 T cells; MHC II works with CD4 T cells. Human MHC proteins are called HLA.

CONNECT Major histocompatibility **complex**; human **leukocyte antigen** is the human naming system.

MHC class I

Major histocompatibility complex class I: a display protein on almost all cells with a nucleus. It usually shows pieces of proteins made inside that cell to CD8 T cells. This allows those T cells to check for infection or abnormality. Human examples are HLA-A, HLA-B and HLA-C.

CONNECT Usually intracellular **protein** → MHC I → **CD8 T cell**. Low MHC I can reduce NK inhibition.

HLA-A, HLA-B, HLA-C

The three main classical human MHC class I gene groups and their display proteins. People inherit versions from both parents. Their peptides are inspected by conventional CD8 T cells.

CONNECT All are classical human **MHC I** types.

Beta-2 microglobulin

Beta-2 microglobulin: the small protein partnered with the main chain of an MHC I molecule. It helps the MHC I display structure remain stable; it is not an inflammasome component.

CONNECT Partners with the **MHC I heavy chain**; not an **NLRP3 inflammasome** component.

TAP

Transporter associated with antigen processing: a protein transporter that moves peptides into the endoplasmic reticulum, an internal cell compartment. There they can be loaded onto MHC I for display at the cell surface.

CONNECT Transporter associated with **antigen** processing → peptides into ER → **MHC I** loading.

05 Antigen recognition and display (continued)

MHC class II

Major histocompatibility complex class II: display proteins mainly on dendritic cells, macrophages and B cells. They usually show fragments of material taken up from outside the cell to CD4 helper T cells. A cell with MHC II generally also has MHC I.

CONNECT Usually taken-up **protein** → MHC II → **CD4 T cell**. MHC II cells generally also express **MHC I**.

HLA-DP, HLA-DQ, HLA-DR

The main human MHC class II gene groups and their display proteins. They are expressed mainly by professional APCs and present peptides to CD4 T cells.

CONNECT Human **MHC II** types; paired with **CD4** helper T cells.

CD1 / CD1d

Cluster of differentiation 1: a family of surface proteins that display fatty molecules to certain T cells. CD1d is used by many natural killer T cells. Unlike ordinary MHC, these proteins mainly display lipids rather than protein fragments.

CONNECT Lipid display to specialised T cells; CD1d is linked to **NKT** cells.

Immunological synapse

In this context, the organised contact area between a T cell and another cell. Receptors and signalling proteins gather there so recognition, supporting signals and sometimes targeted killing can happen efficiently. It is not a nerve synapse.

CONNECT Contact zone brings together recognition, costimulation and **adhesion molecules**.

HLA-B51

A particular HLA-B antigen group, commonly written HLA-B*51 for the allele family. It is a human MHC class I variant.

CONNECT Its groove holds peptides for **CD8** T-**cell** recognition; it is not a separate **MHC** class.

Anchor amino acid

A peptide residue whose side chain fits a pocket in an MHC molecule and helps hold the peptide in the groove.

CONNECT Other exposed **peptide** residues help form the surface contacted by the **TCR**.

ITAM

Immunoreceptor tyrosine-based activation motif: a short sequence in a signalling protein that can be chemically modified to recruit signalling enzymes.

CONNECT **CD3** carries these signalling motifs; the **TCR** recognises **antigen** but needs signalling partners.

06 CD markers and receptor partnerships

TCR asks "does it match?" CD28 asks "shall we respond?" CTLA-4 says "ease off".

CD / cluster of differentiation

Cluster of differentiation is the naming system for many cell-surface molecules. A CD marker can help identify a cell and have a functional job. A plus sign, as in CD4+, means the cell expresses that marker.

CONNECT A numbered **cell**-surface **molecule**, not a **cytokine** number.

CD2

Cluster of differentiation 2: a surface protein on T cells and NK cells that helps them attach to other cells and supports signalling. It is not the antigen-recognition part of the T-cell receptor.

CONNECT T-**cell** / NK-**cell** adhesion and signalling support; not the **antigen**-binding **TCR**.

CD3

Cluster of differentiation 3: a group of signalling proteins attached to the T-cell receptor. The receptor recognises the target; CD3 helps pass that recognition signal into the T cell.

CONNECT **TCR** binds; CD3 signals. A useful T-**cell** marker.

CD4

Cluster of differentiation 4: a surface protein found on helper T cells and some other cells. It assists T-cell recognition of peptide on MHC II. The plus sign means the cell expresses CD4.

CONNECT **TCR** co-**receptor** for **MHC II**; typical of helper and regulatory T cells.

CD8

Cluster of differentiation 8: a surface protein that assists T-cell recognition of peptide on MHC I. It is typical of cytotoxic T cells; the plus sign means the cell expresses CD8.

CONNECT **TCR** co-**receptor** for **MHC I**; typical of cytotoxic T cells.

CD16 / Fc-gamma receptor III

Cluster of differentiation 16: a receptor for the tail of IgG antibodies. On NK cells it helps detect and kill cells coated with IgG, linking an antibody response to a killing cell.

CONNECT **IgG**-coated target → NK CD16 → **antibody**-dependent cellular cytotoxicity (ADCC).

CD19

Cluster of differentiation 19: a surface protein used to identify most B cells. It also helps strengthen signals from the B-cell receptor when the B cell encounters its target.

CONNECT B-**cell** marker and **BCR** signalling amplifier.

06 CD markers and receptor partnerships (continued)

CD20

Cluster of differentiation 20: a protein found on many developing and mature B cells and used as a B-cell marker. It is generally lost when a B cell becomes an antibody-secreting plasma cell.

CONNECT B-**cell** marker; plasma cells generally do not retain it.

CD25 / IL-2 receptor alpha chain

CD25 is the alpha chain of the receptor for IL-2, a cytokine that supports T-cell growth and survival. Together with other receptor chains, it forms a high-affinity IL-2 receptor; regulatory T cells usually express a lot of CD25.

CONNECT Part of high-affinity **IL-2 receptor**; abundant on Tregs, also on activated T cells.

CD28

Cluster of differentiation 28: a supporting-signal receptor on T cells. When B7 on an antigen-presenting cell binds it, CD28 helps a naive T cell become fully activated after recognising its antigen.

CONNECT On **T cell**; binds B7 on **APC** → positive costimulation.

B7-1 / CD80

One of the B7 costimulatory ligands on antigen-presenting cells. Binding CD28 helps activate T cells; binding CTLA-4 contributes to restraint. CD80 and B7-1 are two names for the same molecule.

CONNECT On **APC** → binds **CD28** or **CTLA-4**.

B7-2 / CD86

The other main B7 ligand on antigen-presenting cells. It helps provide the supporting signal for T-cell activation through CD28 and can also bind CTLA-4. CD86 and B7-2 name the same molecule.

CONNECT Same **receptor** partners as CD80: **CD28** and **CTLA-4**.

CTLA-4

Cytotoxic T-lymphocyte-associated protein 4: a brake on T-cell responses. It binds B7 proteins and limits the supporting signal normally delivered through CD28. Despite its name, it is not a toxin used to kill cells.

CONNECT Competes for B7 and limits T-**cell** costimulation; important in immune regulation.

06 CD markers and receptor partnerships (continued)

CD40

Cluster of differentiation 40: a receptor on B cells and several other antigen-presenting cells. Binding by CD40L on a helper T cell provides help, including support for B-cell growth and changing antibody class.

CONNECT B-**cell** / **APC** side of the CD40-**CD40L** contact; helps support class switching.

CD40L / CD154

CD40 ligand, also called CD154: a surface protein on activated helper T cells that binds CD40 on another cell. This direct-contact signal helps B cells make effective antibody responses. Ligand means the receptor's binding partner.

CONNECT Activated helper-T-**cell** side; defective help can cause **hyper-IgM syndrome**.

Fc receptor / FcR

Proteins on immune cells that recognise antibody tails, rather than the antigen-binding tips. They let a cell respond to antibody-coated targets; different Fc receptors recognise different antibody classes.

CONNECT **Cell receptor** binds the **antibody** tail; Fab is the **antigen**-binding end.

IgE Fc receptor / Fc-epsilon-RI

A high-affinity receptor for the Fc part of IgE. It keeps IgE on mast cells and basophils, allowing them to respond rapidly when matching antigen links neighbouring IgE molecules.

CONNECT **IgE** binds mast cells / basophils; **antigen** cross-links **receptor**-bound **IgE** → release.

Complement receptor

A cell-surface receptor that binds a complement protein or fragment. Phagocytes use certain complement receptors to recognise C3b- or iC3b-coated material and help engulf it.

CONNECT Recognises **complement**-coated targets; **iC3b** still serves as an engulfment tag.

Chemokine receptor

A surface receptor that detects a chemokine. Its signalling helps guide cell movement and activation. A chemokine receptor is the receiver, not the released chemokine itself.

CONNECT Detects **chemokine** gradients, linking a message such as **CXCL8** to **cell** movement.

06 CD markers and receptor partnerships (continued)

Adhesion molecule

Adhesion molecules help cells attach to each other or to surfaces. Contact-dependent communication requires cells to touch, rather than a freely released signal travelling through fluid. Some immune signals can use membrane-bound molecules.

CONNECT Helps immune cells attach to vessel linings or other cells during migration and signalling.

CD14

A molecule that helps deliver bacterial lipopolysaccharide to the TLR4-MD2 recognition system. It is also used to identify monocyte subsets.

CONNECT LBP → CD14 → **TLR4**-MD2; CD14 is not the **cytokine IL-14**.

CD23 / Fc-epsilon-RII

The low-affinity IgE receptor, expressed on B cells and some other cells. It helps regulate IgE-related responses.

CONNECT Different from high-affinity Fc-epsilon-RI on mast cells.

CD56 / NCAM

Neural cell adhesion molecule, used with other markers to identify human NK-cell populations.

CONNECT **CD3**-negative, CD56-positive cells are commonly counted as NK cells; CD56 alone is not exclusive to them.

CD45RA

A form of the CD45 cell-surface protein used to distinguish T-cell populations.

CONNECT **Naive** T cells and TEMRA cells can both express it; combine markers rather than interpreting it alone.

ICOS / CD278

Inducible T-cell costimulator: a receptor on activated T cells that supports helper-cell responses, especially B-cell help.

CONNECT Binds ICOS ligand on an interacting **cell**; important for Tfh function.

ICOS ligand / ICOSL / CD275

The binding partner for ICOS, found on B cells and other antigen-presenting cells.

CONNECT ICOSL on the **B cell** → ICOS on the helper **T cell**.

OX40 / CD134

A receptor induced on activated T cells that can promote their survival and continued response.

CONNECT Binds OX40 ligand; distinct from the initial **CD28**-B7 costimulation pair.

06 CD markers and receptor partnerships (continued)

OX40 ligand / OX40L / CD252

A surface signal on activated antigen-presenting cells that binds OX40 on T cells.

CONNECT OX40L-OX40 supports an ongoing T-**cell** response.

PD-1 / CD279

An inhibitory receptor that limits T-cell activity when engaged by its ligands.

CONNECT PD-L1 or PD-L2 → PD-1 → reduced activation signals.

Remember PD-1: a brake, not the antigen detector.

PD-L1 / PD-L2 / PD-L

Ligands for PD-1 that can reduce an interacting T cell's activity. PD-L1 is also labelled PD1L in one diagram.

CONNECT An inhibitory partner system; not the same pair as **CTLA-4** and B7.

CXCR5

A chemokine receptor that guides B cells and follicular helper T cells towards B-cell follicles.

CONNECT Responds to CXCL13; helps bring B cells and Tfh cells together.

Fc-alpha receptor / CD89

A receptor that recognises the Fc portion of IgA on certain myeloid cells.

CONNECT Can connect **IgA**-coated targets to **phagocyte** responses; not the epithelial **IgA** transporter.

Polymeric immunoglobulin receptor / pIgR

An epithelial receptor that transports J-chain-containing IgA or IgM across an epithelial barrier.

CONNECT Part remains attached as the **secretory component** after transport.

CR1 / CD35

Complement receptor 1, which binds complement-coated material, especially C3b and C4b.

CONNECT Helps immune-**complex** clearance and **phagocyte** recognition; can support **complement** regulation.

CR3 / CD11b-CD18

A two-part adhesion and complement receptor on many myeloid cells that recognises iC3b-coated targets.

CONNECT Promotes attachment and uptake; CD11b and CD18 are its **protein** subunits.

06 CD markers and receptor partnerships (continued)

CR4 / CD11c-CD18

A two-part receptor on dendritic cells and other myeloid cells that can bind iC3b-coated material.

CONNECT Shares CD18 with CR3 but uses CD11c as its other subunit.

07 Cytokines: inflammation and recruitment

IL-1 + TNF: activate the vessels. IL-6: call the liver. IL-8: invite neutrophils.

Cytokine

A small protein message released by cells. It binds a receptor on a target cell and changes what that cell does, for example making it multiply, become active or produce inflammatory substances.

CONNECT A **protein** signal from a **cell** → **receptor** on a **target cell** → changed behaviour.

Interleukin / IL

A naming group of cytokines, the small proteins cells use to send messages. IL means interleukin. The number identifies the molecule, not how powerful it is or a step in a sequence.

CONNECT Number = name, not sequence or strength. Many non-**leukocyte** cells also produce interleukins.

Chemokine

A cytokine that helps direct cell movement. Cells can follow its concentration gradient toward a site where they are needed; CXCL8 attracts neutrophils.

CONNECT A movement-guiding **cytokine**; **CXCL8** is the key **neutrophil** example.

IL-1

Interleukin-1: a group of inflammation-promoting cytokines, especially IL-1 alpha and IL-1 beta. They contribute to fever and help activate blood-vessel lining cells so immune cells can reach affected tissue.

CONNECT Main family members **IL-1 alpha** and **IL-1 beta**; inflammation and fever.

IL-1 alpha

An inflammation-promoting IL-1 family cytokine. It can be present in cells and contribute to alarm signalling when tissue is damaged. Unlike IL-1 beta, its precursor can already have biological activity.

CONNECT Related to **IL-1 beta** but not interchangeable in processing.

07 Cytokines: inflammation and recruitment (continued)

IL-1 beta

Interleukin-1 beta: a major inflammation-promoting cytokine. It helps cause fever and activates blood-vessel lining cells so that white blood cells can leave the circulation and reach affected tissue.

CONNECT **NLRP3 inflammasome** → **caspase-1** → mature IL-1 beta → fever / endothelial activation.

IL-6

Interleukin-6: a cytokine that contributes to fever and tells the liver to produce acute-phase proteins, including CRP and fibrinogen. These are part of the body's response to inflammation.

CONNECT Macrophages and other cells → liver → **CRP** / **fibrinogen**; also supports fever.

Remember 6 sends the liver into synthesis.

CXCL8 / IL-8

A chemokine also called interleukin-8. It attracts neutrophils toward an inflamed area and helps activate them.

CONNECT Inflamed tissue → CXCL8 gradient → **neutrophil** arrival. IL-8 and CXCL8 are the same signal.

Remember 8: neutrophils migrate.

TNF / TNF-alpha

Tumour necrosis factor alpha: a major inflammation-promoting cytokine. It helps activate blood-vessel linings and recruit immune cells; very high body-wide release can contribute to dangerous circulation problems.

CONNECT **Macrophage** alarm → vessel activation and leak; systemic excess can contribute to shock.

IL-18

Interleukin-18: a cytokine that supports immune activation, particularly interferon-gamma production in suitable cytokine environments. Like IL-1 beta, it is made as a precursor that can be activated by caspase-1.

CONNECT Caspase-1 processes its precursor; with **IL-12** it promotes **IFN-gamma** production.

08 Cytokines: helper programmes and brakes

2 grows T cells; 4 switches to IgE; 5 supports eosinophils; 10 turns inflammation down; 12 supports Th1.

IL-2

Interleukin-2: a cytokine important for T-cell multiplication and survival. Regulatory T cells also depend on it; CD25 is part of the receptor that helps them respond efficiently.

CONNECT Activated **T cell** → T-**cell** expansion and **Treg** survival; **CD25** helps receive it.

IL-4

Interleukin-4: a cytokine that encourages helper T cells to develop a Th2 programme and helps B cells switch to making IgE. It is important in type-2 responses, including allergy.

CONNECT **Th2** programme + B-**cell** switching to **IgE**; not **IL-14**.

IL-5

Interleukin-5: a cytokine that supports the production, survival and activity of eosinophils. It helps link Th2 or ILC2 responses to defence against worms and to allergic inflammation.

CONNECT **Th2** / **ILC2** → **eosinophil** production, survival and activity.

IL-10

Interleukin-10: a cytokine that limits inflammation, including reducing inflammatory signals from macrophages and dendritic cells. It helps stop a useful defence response from causing excessive tissue damage.

CONNECT Limits inflammatory **macrophage** / dendritic-**cell** output; supports controlled responses.

IL-12

Interleukin-12: a cytokine made by cells such as dendritic cells and macrophages. It activates NK cells, encourages Th1 development and promotes production of interferon gamma.

CONNECT APCs → NK activation / **Th1** development → **IFN-gamma** → stronger **macrophage** killing.

IL-13

Interleukin-13: a cytokine that increases mucus production and changes barrier tissues in type-2 responses. It contributes to worm expulsion and can also drive features of allergic airway disease.

CONNECT **Th2** / **ILC2** → mucus and barrier changes; with **IL-4** can support human **IgE** switching.

08 Cytokines: helper programmes and brakes (continued)

IL-14

Interleukin-14 is a historical name proposed for a high-molecular-weight B-cell growth factor, meaning a protein studied for supporting B-cell multiplication. It is not the characteristic Th2 cytokine being tested here; that is IL-4.

CONNECT Historical B-**cell** growth-factor name used as a distractor. It is not the standard **Th2** answer.

IL-17

Interleukin-17: a cytokine that makes tissue cells release signals that recruit neutrophils. It supports defence against extracellular bacteria and fungi, especially at body surfaces.

CONNECT **Th17** / **ILC3** → tissue signals → **neutrophil** recruitment; extracellular bacteria and **fungi**.

IL-22

Interleukin-22: a cytokine acting mainly on barrier cells such as intestinal or skin-lining cells. It helps them maintain the barrier, repair damage and produce antimicrobial substances.

CONNECT **Th17**-related responses / **ILC3** → epithelial antimicrobial defence and repair.

Remember 22 tends the barrier.

TGF-beta

A cytokine involved in immune regulation, tissue repair and cell differentiation. Tregs can use it to restrain responses. Its effects depend on context: it is not always simply an off-switch and can support other differentiation programmes with additional signals.

CONNECT Transforming growth factor beta; regulation and tissue repair; with other signals, context-dependent effects.

IL-7

A cytokine important for the survival and development of lymphocytes, particularly T cells.

CONNECT IL-7 **receptor** signals help maintain **naive** and **memory** **T cells**.

IL-9

A cytokine that can support mast cells and mucosal responses; it participates in some allergic and parasite responses.

CONNECT Appears in the helper-**cytokine** figure; it is not restricted to one helper subset.

IL-21

A cytokine produced by helper T cells, especially Tfh cells, that supports B-cell responses and other immune functions.

CONNECT IL-21 **receptor** on B cells → differentiation and **antibody**-response support.

08 Cytokines: helper programmes and brakes (continued)

IL-17A / IL-17F

Related members of the IL-17 cytokine family that stimulate barrier cells to promote inflammatory recruitment and antimicrobial defence.

CONNECT **Th17** / **ILC3** responses → IL-17A or IL-17F → signals that recruit neutrophils.

09 Interferons and blood-cell growth signals

Type I IFN: antiviral state. Type II IFN-gamma: activate macrophages. G-CSF makes; CXCL8 moves.

Interferon / IFN

A group of cytokines that change immune activity and help cells resist infection. Type I interferons commonly promote antiviral defences; interferon gamma is type II and strongly activates macrophages.

CONNECT **Cytokine** family, not a **cell** and not an **antibody**.

Type I interferons

A family of interferon signals including alpha, beta, omega and epsilon. They act through the same receptor system and help cells turn on antiviral defences. Interferon gamma belongs to a different type.

CONNECT Alpha, beta, omega and epsilon in these decks; not gamma.

IFN-alpha

Interferon alpha: type I interferon signals made during infection. They tell nearby cells to produce proteins that make viral replication harder and help coordinate other antiviral defences.

CONNECT Type I → antiviral gene expression in responding cells.

IFN-beta

Interferon beta: a type I interferon made by many cells responding to infection. It binds receptors on cells and activates genes that help resist viruses; it does not directly act as an antibody.

CONNECT Type I → antiviral protection through the receiving **cell**'s machinery.

IFN-omega

Interferon omega: a member of the type I interferon family. It uses the type I interferon receptor and helps activate antiviral responses. Omega is its name, not a separate interferon type.

CONNECT Also type I; omega is not a separate numbered type.

09 Interferons and blood-cell growth signals (continued)

IFN-epsilon

Interferon epsilon: a type I interferon involved particularly in protection at reproductive-tract surfaces. It is not a characteristic cytokine produced by Th2 helper cells.

CONNECT Type I, particularly relevant to reproductive-tract epithelial protection.

IFN-gamma / type II interferon

Interferon gamma: a cytokine made by cells including Th1, NK cells and ILC1s. It strengthens macrophages' ability to kill swallowed microbes and promotes defence against intracellular infections.

CONNECT **Th1** / NK / **ILC1** → **macrophage** activation. Not part of type I IFNs.

G-CSF

Granulocyte colony-stimulating factor: a cytokine that tells bone marrow to produce and release more neutrophils. Its name describes its ability to support growth of granulocyte-producing cells.

CONNECT **Granulocyte** colony-stimulating factor → marrow makes and releases neutrophils.

GM-CSF

Granulocyte-macrophage colony-stimulating factor: a protein signal supporting the production and activity of several microbe-fighting white blood cells. Unlike G-CSF, which mainly supports neutrophils, GM-CSF can also support monocytes and related cells.

CONNECT **Granulocyte**-**macrophage** colony-stimulating factor → **granulocyte** and **monocyte/macrophage** support.

EPO

Erythropoietin: a hormone made mainly by the kidneys when oxygen supply is low. It tells bone marrow to produce more red blood cells. It is not the main growth signal for lymphocytes.

CONNECT Erythropoietin → red-**cell** production, not the main **lymphocyte** growth signal.

IFN-kappa

A type I interferon associated particularly with epithelial cells such as skin keratinocytes.

CONNECT Signals through IFNAR1/IFNAR2, like other **type I interferons**.

09 Interferons and blood-cell growth signals (continued)

M-CSF / CSF1

Macrophage colony-stimulating factor: a growth and survival signal for cells of the monocyte-macrophage lineage.

CONNECT Different from **G-CSF**, which strongly supports **neutrophil** production.

IL-2 receptor / IL-2R

The receptor system that receives IL-2. Its high-affinity form contains alpha, beta and common gamma chains.

CONNECT **CD25** is the alpha **chain**, not the entire **receptor**; supports activated T cells and Tregs.

IL-4R alpha / IL-4 receptor

A receptor chain used in IL-4 signalling and in one type of IL-13 receptor.

CONNECT Links type-2 cytokines to cellular responses such as allergy-associated programmes.

IL-6 receptor / IL-6R

The IL-6-binding receptor component that works with gp130 to send signals into cells.

CONNECT **IL-6** is the message; IL-6R helps receive it; gp130 relays it.

gp130 / CD130

A shared signalling component used by the IL-6 family of cytokine receptors.

CONNECT **IL-6 receptor** binding activates a gp130-containing **complex** and downstream signalling.

IL-7R alpha / CD127

The alpha chain of the IL-7 receptor, important for receiving lymphocyte survival signals.

CONNECT **IL-7** → IL-7R → T-**cell** maintenance.

IL-12R beta2

A signalling chain of the IL-12 receptor that helps T cells respond to IL-12.

CONNECT Supports the development of **IFN-gamma**-producing **Th1** responses.

IL-21 receptor / IL-21R

A receptor component that receives IL-21 and partners with the common gamma chain to signal.

CONNECT On B cells, helps translate T-**cell IL-21** into an **antibody** response.

09 Interferons and blood-cell growth signals (continued)

IFNAR1 / IFNAR2

The two receptor chains that together receive type I interferons.

CONNECT IFNAR1 associates with TYK2; IFNAR2 with JAK1; the signal activates STAT proteins.

10 Antibodies: classes and subclasses

M = first mass response. G = goes through placenta. A = at mucosal surfaces. E = allergy / worms. D = displayed on naive B cells.

Antibody / immunoglobulin / Ig

A target-binding protein made by B cells and released in large amounts by plasma cells. Its binding tips recognise particular antigen features; other regions help recruit defence mechanisms.

CONNECT Secreted by plasma cells; membrane form is the **BCR**'s **antigen**-binding component.

IgM

Immunoglobulin M: usually the first antibody class secreted in a primary response. Secreted IgM usually joins five antibody units together, making it good at clumping targets and activating complement.

CONNECT **Monomer** on B cells; usually pentamer when secreted. Strong classical-**complement** activator.

IgD

Immunoglobulin D: found mainly as a surface antigen receptor on mature naive B cells, usually alongside IgM. Only small amounts circulate in blood.

CONNECT Often displayed with **IgM** on mature **naive** B cells.

IgG

Immunoglobulin G: the most abundant antibody class in blood serum. It can neutralise targets and help phagocytes recognise them; some subclasses activate complement. It can also cross the placenta.

CONNECT Major serum **antibody**; neutralisation, opsonisation, some **complement** activation; crosses **placenta**.

IgG1

Immunoglobulin G subclass 1: a common IgG subtype, often important in responses to protein antigens. It can recruit immune cells through its tail and activate complement when appropriately bound.

CONNECT Common anti-**protein** response; Fc-mediated functions and **complement** activation.

10 Antibodies: classes and subclasses (continued)

IgG2

Immunoglobulin G subclass 2: especially important in many responses to bacterial capsule sugars. Its slower development in young children contributes to weaker responses to some pure polysaccharide antigens.

CONNECT Important in responses to bacterial polysaccharides; develops relatively slowly in childhood.

IgG3

Immunoglobulin G subclass 3: a subtype effective at activating complement and recruiting immune-cell functions. It has a relatively long flexible hinge between its arms and tail.

CONNECT Particularly effective **complement** activation; generally shorter serum half-life than most other **IgG**.

IgG4

Immunoglobulin G subclass 4: a subtype often associated with prolonged or repeated antigen exposure. It activates classical complement poorly compared with IgG1 or IgG3.

CONNECT Weak classical-**complement** activation; not simply interchangeable with **IgG1** / **IgG3**.

IgA

Immunoglobulin A: important at mucosal surfaces such as the gut and airways and in secretions such as saliva and breast milk. It helps stop microbes attaching or entering; secreted IgA commonly consists of two joined units.

CONNECT Serum is mainly monomeric; secretions commonly contain dimeric **secretory IgA**.

IgA1

An IgA subclass with a relatively long hinge region between binding arms and tail. It is common in blood and also present in secretions. Some bacterial proteases can cut its hinge.

CONNECT One of two human **IgA** subclasses; predominant in serum.

IgA2

An IgA subclass with a shorter hinge than IgA1, making it more resistant to certain bacterial IgA proteases. It contributes to mucosal defence, particularly in parts of the intestine.

CONNECT Other human **IgA** subclass; important at some mucosal sites.

10 Antibodies: classes and subclasses (continued)

Secretory IgA / sIgA

The form of immunoglobulin A released onto moist body linings, such as the intestine and airways. It commonly consists of two antibody units plus a protective transport-derived component and helps prevent microbes attaching to or crossing the lining.

CONNECT Mucosal exclusion / neutralisation; **J chain** joins units and **secretory component** helps protect them.

IgE

Immunoglobulin E: an antibody class involved in immediate allergic reactions and defence against worms. Much of it is attached to receptors on mast cells and basophils rather than freely circulating.

CONNECT Fc **receptor** on mast cells / basophils; allergen cross-linking triggers release.

IgY

Immunoglobulin Y: an antibody type found in birds and some other vertebrates, including in egg yolk. It is not one of the human antibody classes.

CONNECT A distractor: an **antibody** type in birds and some other vertebrates, not a human isotype.

Autoantibody

Antibodies that bind the body's own molecules. Some contribute to autoimmune disease, but finding an autoantibody does not by itself prove that it is causing damage.

CONNECT **Antibody** directed against self; not every detectable autoantibody means autoimmune disease.

Monoclonal antibody

Antibodies derived from one B-cell clone, with the same antigen-binding specificity. In contrast, polyclonal antibodies come from several clones.

CONNECT One **clone** / one specificity; contrast with polyclonal mixtures.

Polyclonal antibody mixture

A mixture of antibodies made by several B-cell clones, often recognising different features of a target. Monospecific polyclonal means several clones recognise one overall antigen; normal serum contains antibodies against many different antigens.

CONNECT Several clones → several epitopes. Monospecific polyclonal can still target one overall **antigen**.

10 Antibodies: classes and subclasses (continued)

Therapeutic antibody / anti-drug antibody

Therapeutic antibodies are antibodies used as medicines, for example to block a signalling molecule. Anti-drug antibodies are antibodies the patient makes against that medicine and may reduce its effect or cause reactions.

CONNECT **Eculizumab** is a therapeutic **antibody**. A patient can make antibodies against an **antibody** medicine.

Eculizumab

An antibody medicine that binds complement protein C5 and prevents it being cut into C5a and C5b. This reduces both C5a-mediated inflammation and formation of the membrane attack complex. Soliris is a brand name.

CONNECT Binds C5 → prevents **C5a** and **C5b** generation → blocks **MAC** formation. It does not block only **MAC**.

11 Antibody structure and complexes

Fab finds antigen. Fc calls for help. Variable = target choice; heavy-chain constant = class and effector role.

Heavy chain

One of the two longer protein chains in an antibody. Each contributes to antigen binding; its constant region determines the antibody class, such as IgG or IgM.

CONNECT Two per **antibody** unit. Heavy-**chain constant region** defines **IgM** / **IgD** / **IgG** / **IgA** / **IgE**.

Light chain

One of the two shorter protein chains in an antibody. Its variable region pairs with a heavy-chain variable region to form an antigen-binding site.

CONNECT Two per **antibody** unit. Its variable region pairs with a heavy-**chain** variable region.

Variable domain / VH and VL

Parts of the heavy and light chains that differ between antibodies. They form the binding tips, so their shape helps determine which antigen feature the antibody recognises.

CONNECT VH = heavy-**chain** variable domain; VL = light-**chain** variable domain. Together form binding tips.

CDR / hypervariable loops

Complementarity-determining regions: short parts of an antibody's variable regions that differ greatly between antibodies. They form loops at the binding tip and help determine which antigen fits. Complementarity here means matching shape, not the complement system.

CONNECT Complementarity-determining regions: amino-acid loops shape the **antigen**-binding surface.

11 Antibody structure and complexes (continued)

Constant domain

The relatively shared part of an antibody chain within a class. The heavy-chain constant region determines the isotype and many of the defence mechanisms the antibody can recruit.

CONNECT Heavy-**chain** constant domains establish class and Fc-dependent functions.

Fab fragment

Fragment antigen-binding: one arm of an antibody, containing parts of one heavy and one light chain. Its tip recognises the antigen. The other main antibody part, Fc, helps recruit immune cells and other defence mechanisms.

CONNECT Fragment **antigen**-binding: one **antigen**-binding arm, including heavy- and light-**chain** portions.

Fc fragment

Fragment crystallisable: the antibody's tail, formed from heavy-chain constant regions. It does not choose the antigen; it connects the bound antibody to immune cells or complement, depending on antibody class.

CONNECT Fragment crystallisable: tail that binds **Fc receptors** and, for suitable classes, **complement**.

Disulfide / S-S bond

Strong chemical links between sulphur atoms in two cysteine amino acids. They help stabilise a protein's shape and hold antibody chains together. They are not the antibody's antigen-binding site.

CONNECT Covalent links between cysteines help join chains and stabilise immunoglobulin domains.

J chain

Joining chain: a small protein included in secreted pentameric IgM and dimeric IgA. It helps assemble the antibody units and supports recognition by the epithelial transport receptor.

CONNECT Links polymeric **IgM** and dimeric **IgA**; supports transport of polymeric antibodies at mucosa.

Secretory component

The extracellular part of the polymeric immunoglobulin transport receptor, retained on secretory IgA after transport across epithelium. It helps protect IgA in harsh mucosal secretions.

CONNECT Epithelial transport leaves this **receptor** fragment attached to **secretory IgA**.

11 Antibody structure and complexes (continued)

Antibody monomer / dimer / pentamer

These words count joined antibody units, not individual chains. Monomeric IgG has four chains. Secretory IgA commonly joins two units; secreted IgM usually joins five. Oligomer means several joined units.

CONNECT One unit = 2 heavy + 2 light chains; dimer = 2 units; pentamer = 5 units.

Immune complex / immunocomplex

Antigen bound to antibody. These complexes can be cleared by immune cells; in laboratory tests, their formation can also be used to detect or measure an antigen.

CONNECT **Antigen** + **antibody** → may activate classical **complement** or form measurable precipitates.

Opsonin

A molecule that coats a target and makes it easier for a phagocyte to grab and swallow. IgG antibodies and complement fragments such as C3b are important examples; the phagocyte has receptors that recognise these coatings.

CONNECT **IgG**, **C3b** and **iC3b** coat a target; **phagocyte** receptors recognise the coat.

Remember Tag it so a phagocyte can grab it.

Paratope

The antigen-binding surface of an antibody or B-cell receptor.

CONNECT The paratope binds the **antigen**'s **epitope**; variable-region CDR loops help form it.

Remember Paratope = the grip; epitope = the grabbed feature.

Hinge region

A flexible antibody segment between antigen-binding arms and the Fc region in certain antibody classes.

CONNECT Flexibility helps the two binding arms reach differently positioned epitopes.

CH1, CH2, CH3, CH4 / CL

Labels for folded constant domains in heavy chains (CH) and light chains (CL). The number of heavy-chain constant domains varies by antibody class.

CONNECT **IgG** has CH1-CH3; **IgM** and **IgE** have CH1-CH4. These are **protein** domains, not CD markers.

Mu, delta, gamma, alpha, epsilon heavy chains

The class-defining heavy-chain types: mu for IgM, delta for IgD, gamma for IgG, alpha for IgA and epsilon for IgE.

CONNECT Gene diagrams use C-mu, C-delta, C-gamma, C-alpha and C-epsilon for the corresponding constant-region genes.

11 Antibody structure and complexes (continued)

Kappa / lambda light chain

The two types of antibody light chain. One ordinary antibody contains either two kappa or two lambda chains.

CONNECT Either light-**chain** type can pair with different heavy-**chain** classes.

IgA2m(1) / IgA2m(2)

Inherited variants, called allotypes, of the IgA2 subclass.

CONNECT Both are **IgA2**; neither is an additional immunoglobulin class.

Tailpiece

A short extension of a secreted antibody heavy chain that helps some antibodies form multi-unit structures.

CONNECT **IgA** / **IgM** tailpieces participate in assembly with the **J chain**.

Amino / carboxyl terminus: NH2 / COOH

The two ends of a protein chain: an amino-containing start and a carboxyl-containing end. Charge changes with the chemical environment.

CONNECT **Antibody** variable domains lie towards the amino ends; these labels are chemical groups, not receptors.

Carbohydrate / CHO group

A sugar group attached to a protein. CHO in an antibody diagram commonly abbreviates carbohydrate.

CONNECT Antibodies are glycoproteins; attached sugars can influence their stability and Fc functions.

12 Complement: tag, recruit, perforate

C3b = binds the target. C5a = attracts cells. C5b begins the pore. C3a/C5a are messages, not antibodies.

Complement system

A linked system of blood and tissue proteins, mostly circulating in inactive forms. Activation sets off a cascade that tags microbes for swallowing, promotes inflammation and can form membrane-damaging pores.

CONNECT Three activation routes converge on C3; outcomes include opsonisation, inflammation and lysis.

Classical pathway

A route for starting complement, often when C1 recognises antibodies already bound to a target. It leads to C3 activation, target coating, inflammation and potentially a membrane attack complex.

CONNECT **Antigen**-bound **IgM** or suitable **IgG** → C1 → C4/C2 → C3 cleavage.

12 Complement: tag, recruit, perforate (continued)

Alternative pathway

A route that continually starts at a low level and is amplified on surfaces that lack suitable complement controls. It can coat microbial surfaces with C3b without first needing specific antibodies.

CONNECT **C3b** amplification on permissive surfaces; no **antibody** required.

Lectin pathway / MBL

A complement activation route in which recognition proteins such as mannose-binding lectin (MBL) bind microbial carbohydrate patterns. It resembles the classical pathway downstream but does not require antigen-specific antibodies.

CONNECT Mannose-binding lectin detects microbial sugars → uses C4/C2 route to C3.

C1 complex

C1 is a group of proteins that starts the classical complement pathway. C1q is its recognition part: it can bind suitably arranged antibody tails on a target and start activation of the other C1 proteins.

CONNECT **C1q** recognition + associated proteases → early **classical pathway**.

C1q

C1 is a group of proteins that starts the classical complement pathway. C1q is its recognition part: it can bind suitably arranged antibody tails on a target and start activation of the other C1 proteins.

CONNECT Binds clustered Fc regions; **antigen**-bound **IgM** is particularly efficient.

C2

Complement component 2: a blood protein used in the classical and lectin complement pathways. After activation, a piece of C2 joins a piece of C4 to form an enzyme that cuts and activates C3.

CONNECT With C4 fragments helps build classical / lectin **C3 convertase**.

C4

Complement component 4: a blood protein used early in the classical and lectin complement pathways. Its C4b fragment attaches to a surface and helps build the enzyme that activates C3.

CONNECT C4b attaches to surfaces and combines with an active C2 fragment.

12 Complement: tag, recruit, perforate (continued)

C3

A central complement protein that is cut during complement activation. C3b helps coat targets for phagocytosis; C3a promotes inflammation.

CONNECT Central convergence **protein** → **C3a** + **C3b**.

C3 convertase

An enzyme complex assembled during complement activation. Its job is to split C3 into C3a and C3b. Different initiating pathways assemble different C3 convertases but reach the same central cleavage step.

CONNECT A multi-**protein enzyme complex** that cleaves C3; not a single extra **cytokine**.

C3a

The smaller signalling fragment released when complement protein C3 is cut. It helps promote inflammation. Unlike C3b, it is not the main fragment that coats a microbe for swallowing.

CONNECT Small soluble inflammatory fragment; does not serve the same coating role as **C3b**.

C3b

A fragment formed when complement protein C3 is cut. It attaches to a target surface and helps phagocytes recognise and swallow that target; it also helps continue the complement reaction.

CONNECT Surface-bound **opsonin** and **complement**-amplification component.

iC3b

A further-cut form of C3b. The i means inactivated: it can no longer do C3b's enzyme-building job, but it still coats targets and helps phagocytes swallow them. Inactivated does not mean useless.

CONNECT Processed **C3b**: no longer builds active convertase, but remains an effective **opsonin**.

C5

A complement protein cut into C5a and C5b. C5a strongly promotes inflammation and cell recruitment; C5b starts assembly of the membrane attack complex.

CONNECT Cleaved into **C5a** and **C5b**; **eculizumab** blocks this cleavage.

12 Complement: tag, recruit, perforate (continued)

C5a

A small fragment released when complement protein C5 is cut. It is a powerful signal that attracts and activates white blood cells and promotes inflammation. It is not part of the membrane pore.

CONNECT Potent inflammatory / **cell**-recruiting signal, especially for neutrophils.

C5b

The larger fragment left after C5 is cut. It starts assembly of the membrane attack complex by binding later complement proteins. C5a sends inflammatory signals; C5b helps build the membrane-damaging structure.

CONNECT Initiates terminal **complement** assembly; different function from **C5a**.

C6, C7, C8, C9

Terminal complement proteins that assemble after C5b appears. Together they form the membrane attack complex; these are proteins, not cells. C9 helps complete the pore.

CONNECT Sequentially assemble with **C5b**; multiple C9 molecules contribute to the membrane pore.

MAC / C5b-9

A pore-forming structure built from complement proteins C5b through C9. It inserts into susceptible membranes and can damage or kill the target.

CONNECT Membrane attack **complex** → susceptible membrane damage; especially relevant to certain **Gram-negative** bacteria.

C1r / C1s

The enzyme subunits of the C1 complex. Recognition by C1q activates C1r, which activates C1s.

CONNECT C1s cleaves C4 and C2 to help assemble the classical **C3 convertase**.

C4b / C4a

C4 fragments produced during classical or lectin pathway activation. C4b attaches to a surface and participates in convertase assembly; C4a is the smaller released fragment.

CONNECT Do not assume C4a has the same established potency as **C3a** or **C5a**.

Factor B / FB / Bb

Factor B binds C3b; cleavage releases Ba and leaves the enzyme fragment Bb associated with C3b.

CONNECT C3bBb is the alternative-pathway **C3 convertase**.

12 Complement: tag, recruit, perforate (continued)

Factor D / FD

An enzyme that cleaves factor B when it is appropriately bound in the alternative pathway.

CONNECT **C3b** + factor B + factor D → C3bBb.

Properdin

A protein that stabilises alternative-pathway convertases and helps sustain complement activation on a target.

CONNECT Keeps C3bBb active longer; factor H has an opposing regulatory role.

Ficolin

A soluble pattern-recognition protein that binds certain microbial chemical patterns and can activate the lectin complement pathway.

CONNECT Like MBL, it associates with MASP enzymes.

MASP-1 / MASP-2

MBL-associated serine proteases: enzymes linked to lectin-pathway recognition proteins.

CONNECT MASP-2 cleaves C4 and C2; MASP-1 assists pathway activation.

MAp proteins / MAPs

Non-enzymatic MBL-associated proteins, including MAp19 and MAp44, involved in regulation of lectin-pathway complexes.

CONNECT The **complement** figure labels these MAPs; do not confuse them with MAP kinases.

C1 inhibitor / C1-INH

A protein that inhibits activated enzymes in the classical and lectin complement pathways and other blood-protein systems.

CONNECT Restrains **C1r / C1s** and MASPs; a regulator rather than the C1 recognition **complex**.

Factor H / FH

A complement regulator that helps limit alternative-pathway amplification, especially on protected host surfaces.

CONNECT Promotes convertase breakdown and helps factor I inactivate **C3b**.

Factor I / FI

An enzyme that cuts C3b or C4b when suitable helper proteins are present, limiting complement activation.

CONNECT With cofactors, can convert **C3b** into **iC3b**: less cascade amplification but retained tagging activity.

12 Complement: tag, recruit, perforate (continued)

C4-binding protein / C4BP

A soluble complement regulator that binds C4b and helps control classical and lectin pathway convertases.

CONNECT Acts as a cofactor for factor I-mediated C4b inactivation.

C5 convertase

A complement enzyme complex that cleaves C5 into C5a and C5b.

CONNECT An extra **C3b** associates with a **C3 convertase**; **C5a** recruits, while **C5b** initiates **MAC** assembly.

C5b-8

An intermediate terminal-complement complex containing C5b, C6, C7 and C8.

CONNECT Recruits C9 to form the mature membrane attack **complex**.

C4b2a / C4b2b nomenclature

Two naming conventions for the classical and lectin C3 convertase. Traditional teaching uses C4b2a; some sources rename the retained large C2 fragment C2b.

CONNECT The diagrams use both conventions. Recognise the same functional **complex** rather than treating them as different pathways.

13 Danger sensors and signalling complexes

Sensor detects -> signalling proteins relay -> transcription factors change gene activity. Inflammasomes activate an enzyme.

PRR

Pattern-recognition receptor: an innate sensor for common microbial features or signs of damage. Unlike BCR and TCR specificity, its recognition system is not created by V(D)J rearrangement in each individual lymphocyte.

CONNECT TLRs and **NLRP3** are examples of innate recognition systems.

TLR / Toll-like receptor

A group of innate immune sensors that recognise common microbial features or certain danger signals. Binding starts signalling inside the cell, helping it produce inflammatory cytokines and supporting signals for other immune cells.

CONNECT Detection → NF-kappaB / **AP-1** / **IRFs** → cytokines, costimulators and sometimes interferons.

13 Danger sensors and signalling complexes (continued)

TLR4

Toll-like receptor 4: an innate immune receptor involved in detecting bacterial lipopolysaccharide. It triggers signalling that promotes inflammation; it is not the same receptor system as a T-cell receptor.

CONNECT Recognises LPS through a **receptor** system with accessory molecules; not **CD4**.

Transcription factor

Proteins that control whether particular DNA instructions are copied into RNA. They can help turn groups of genes on or off; after microbial detection, this can make a cell produce cytokines.

CONNECT Controls gene use; it is not the same as an extracellular **cytokine**.

NF-kappaB / NF-kB

Nuclear factor kappa B: a family of gene-control proteins. When activated by signals such as microbial detection, it helps turn on genes for inflammation, cell survival and immune defence.

CONNECT Nuclear factor kappa B → inflammatory and **cell**-survival genes.

AP-1

Activator protein 1: a group of gene-control proteins that act together. Signals from receptors can activate it, helping change production of proteins involved in immune responses, growth and other cell activities.

CONNECT Activator **protein** 1 → gene-expression changes following **receptor** signals.

IRF

Interferon regulatory factors: a family of proteins that control gene activity. Some help switch on interferons and other antiviral genes when a cell detects an infection.

CONNECT **Interferon** regulatory factors → antiviral / **interferon** gene programmes.

Inflammasome

A group of proteins that assembles inside a cell after certain danger signals. It activates an enzyme called caspase-1, which helps turn IL-1 beta and IL-18 into active inflammatory cytokines.

CONNECT Sensor + adaptor (in many types) + **enzyme** precursor → active **caspase-1**.

13 Danger sensors and signalling complexes (continued)

NLRP3

NLR family pyrin domain-containing 3: an internal danger-sensor protein. When activated by disturbed cell conditions, it can assemble with ASC and procaspase-1 into an inflammasome, a protein complex that activates inflammatory signals. Other inflammasomes can use different sensors.

CONNECT NLR family pyrin domain-containing 3; sensor in ONE **inflammasome** type.

ASC

Apoptosis-associated speck-like protein containing a CARD: a linking protein in several inflammasomes. Its job here is to connect a danger sensor to procaspase-1, helping that enzyme become active. CARD is the name of one of its protein-interaction domains.

CONNECT Adaptor linking **NLRP3** to **procaspase-1**; not an **antigen**-presenting **cell** (**APC**).

Procaspase-1

Procaspase-1 is the inactive precursor of the enzyme caspase-1. When an inflammasome activates it, caspase-1 cuts precursor forms of IL-1 beta and IL-18 into active cytokines and can help trigger inflammatory cell death.

CONNECT Inactive precursor recruited to **inflammasome** → active **caspase-1**.

Caspase-1

An inflammatory protein-cutting enzyme activated in inflammasomes. It matures IL-1 beta and IL-18 and helps trigger inflammatory cell death. Procaspase-1 is its inactive precursor.

CONNECT Processes pro-**IL-1 beta** and pro-**IL-18** into active cytokines.

Caspase family

A family of enzymes that cut other proteins. Some carry out organised cell death, while others, such as caspase-1, activate inflammatory signals. The individual caspase number matters.

CONNECT Some execute apoptosis; **caspase-1** has inflammatory roles. Not every caspase has the same job.

TLR2

A Toll-like receptor that recognises microbial components, commonly bacterial lipoproteins, with partner receptors.

CONNECT The **Candida** figure places it beside **TLR4** and fungal carbohydrate receptors.

13 Danger sensors and signalling complexes (continued)

Mannose receptor / MR / CD206

A sugar-binding surface receptor that helps some cells recognise and take up material bearing certain carbohydrates.

CONNECT Recognises sugar patterns; distinct from soluble mannose-binding lectin.

Dectin-1

A receptor that recognises beta-glucans in fungal cell walls and promotes antifungal responses.

CONNECT Fungal beta-glucans → Dectin-1 → **phagocyte** activation.

LBP / LPS-binding protein

A soluble protein that binds bacterial lipopolysaccharide and helps transfer it to recognition partners.

CONNECT LBP → **CD14** → MD2-**TLR4**; recognition can then induce inflammatory cytokines.

MD2 / TLR4-MD2-CD14 system

MD2 is the LPS-binding partner associated with TLR4. CD14 helps transfer LPS to this system.

CONNECT MD2 binding supports **TLR4** activation; all three labels have different jobs.

MyD88

An intracellular adaptor protein: a connector that assembles signalling partners after most Toll-like receptors are activated.

CONNECT Links **receptor** activation to **IRAK** / **TRAF6** and inflammatory gene expression.

TIRAP / Mal

An adaptor that helps recruit MyD88 to certain activated Toll-like receptors.

CONNECT Important in **TLR2** / **TLR4** signalling; a connector, not a secreted **cytokine**.

TRIF

An adaptor that carries signals from TLR3 and from internalised TLR4 towards interferon and inflammatory responses.

CONNECT Can activate **IRF3** → type I **interferon** production.

TRAM

TRIF-related adaptor molecule: a connector that helps TLR4 use the TRIF signalling route.

CONNECT One source figure reads TAM at this position; the established **TLR** adaptor name is TRAM.

13 Danger sensors and signalling complexes (continued)

IRAK

Interleukin-1 receptor-associated kinase family: enzymes that relay signals in MyD88-dependent pathways.

CONNECT IRAK proteins help connect the **receptor**-adaptor assembly to **TRAF6**.

TRAF6

An intracellular signalling protein that helps assemble and regulate downstream immune-signalling complexes.

CONNECT Helps activate NF-kappaB and **MAPK** pathways after some receptors detect danger.

I-kappaB / IKK

I-kappaB restrains NF-kappaB. IKK means I-kappaB kinase: an enzyme complex that helps remove this restraint.

CONNECT IKK activity → loss of inhibitory I-kappaB → NF-kappaB can enter the **nucleus**.

MAPK

Mitogen-activated protein kinases: enzymes in signal-relay cascades that change protein activity and gene expression.

CONNECT Can activate **AP-1**; unrelated to **complement** MAp proteins.

IRF3

Interferon regulatory factor 3, a protein that switches on antiviral genes after suitable danger signals.

CONNECT **TRIF**-linked pathways can activate IRF3 → type I **interferon** production.

LRR / NACHT / PYD / CARD

Protein domains in the inflammasome diagram. LRR means leucine-rich repeats; NACHT is an ATP-using assembly domain; PYD and CARD are matching interaction modules.

CONNECT **NLRP3** PYD binds **ASC** PYD; **ASC** CARD recruits **procaspase-1** CARD. They are **protein** parts, not four separate cytokines.

JAK1 / TYK2

Janus-family protein kinases: enzymes that relay signals from cytokine receptors by adding phosphate groups to target proteins.

CONNECT Type I **interferon receptor** activation uses JAK1 and TYK2 to activate STAT proteins.

STAT1

Signal transducer and activator of transcription 1: a protein that relays signals and can regulate genes in the nucleus.

CONNECT Works in **interferon** responses; can pair with **STAT2** or another STAT1 **molecule**.

13 Danger sensors and signalling complexes (continued)

STAT2

A signalling and gene-regulatory protein especially important in type I interferon responses.

CONNECT **STAT1** + STAT2 + IRF9 form the ISGF3 transcription **complex**.

STAT3

A signalling and gene-regulatory protein used by cytokines including IL-6 and IL-10.

CONNECT Its effects depend on the **receptor** and **cell**; the same **protein** can participate in different responses.

IRF9 / ISGF3

IRF9 is a DNA-targeting partner that combines with STAT1 and STAT2 to form ISGF3, a gene-regulating complex.

CONNECT ISGF3 binds **interferon**-stimulated response elements to activate antiviral programmes.

ISRE / GAS

Short DNA response sequences, not proteins. ISRE means interferon-stimulated response element; GAS means gamma-activated sequence.

CONNECT ISGF3 binds ISRE; **STAT1** pairs can bind GAS. These are gene-control landing sites.

BTK

Bruton tyrosine kinase, an enzyme involved in B-cell receptor signalling and B-cell development.

CONNECT Loss of its function can cause **X-linked agammaglobulinaemia** with very few mature B cells.

AID

Activation-induced cytidine deaminase, an enzyme that starts DNA changes used in antibody class switching and variable-region mutation.

CONNECT Helps activated B cells change **antibody** class and improve binding; **antigen** does not directly rewrite the **receptor**.

14 Killing molecules and soluble defence proteins

Swallowing is not killing. NADPH oxidase powers the respiratory burst; lysozyme cuts walls; perforin supports cell killing.

NADPH

Reduced nicotinamide adenine dinucleotide phosphate: a molecule that carries transferable electrons. Phagocytes use those electrons to help make reactive oxygen chemicals for killing swallowed microbes.

CONNECT Electron donor used by **NADPH oxidase**; not the **enzyme** itself.

NADPH oxidase

A group of proteins that uses electrons from NADPH to turn oxygen into reactive chemicals inside phagocytes. This starts an important microbe-killing reaction; defects in this system cause chronic granulomatous disease.

CONNECT **Phagocyte enzyme complex** → **ROS**; defective in **chronic granulomatous disease** (CGD).

Reactive oxygen species / ROS

Chemically reactive substances containing oxygen, including superoxide and hydrogen peroxide. Phagocytes produce them to damage swallowed microbes; if uncontrolled, they can also damage the body's own cells.

CONNECT Respiratory burst products help kill microbes inside phagocytes.

Hydrogen peroxide / H2O2

A reactive oxygen-containing molecule made downstream of the phagocyte oxidative burst. It contributes to antimicrobial chemistry; uncontrolled amounts can also damage host tissue.

CONNECT One **ROS**; **catalase** breaks it down.

Catalase

An enzyme that breaks hydrogen peroxide into water and oxygen. Catalase-positive means an organism makes this enzyme; it does not mean the organism makes complement.

CONNECT Microbial catalase removes peroxide. Catalase-positive organisms are important in CGD.

Lysozyme

An enzyme in substances such as tears and saliva and inside some immune cells. It cuts links in bacterial peptidoglycan, weakening the cell wall. It is a molecule, not the lysosome organelle.

CONNECT Cuts beta-1,4 sugar links between **NAG** and **NAM** in bacterial **peptidoglycan**.

Remember Lysozyme = enzyme. Lysosome = compartment.

14 Killing molecules and soluble defence proteins (continued)

Defensin

Small antimicrobial peptides made by several immune and barrier cells. They damage susceptible microbes partly by disrupting or forming pores in their membranes.

CONNECT Antimicrobial **peptide**; Paneth cells and other cells make them; damages microbial membranes.

Perforin

A protein released by cytotoxic T cells and NK cells that helps deliver killing enzymes into a target cell. Despite both damaging membranes, perforin and the complement membrane attack complex are different systems.

CONNECT Released by CTLs / NK cells; helps granzymes access target-**cell** interior.

Granzyme

A protein-cutting enzyme released by cytotoxic T cells and NK cells. Once delivered into a target cell, certain granzymes activate pathways that make it dismantle itself by apoptosis.

CONNECT Cytotoxic granule **enzyme** → target-**cell** apoptosis, working with **perforin**.

Histamine

A small chemical mediator, not a protein cytokine. It rapidly increases local vessel permeability and contributes to symptoms such as itching in immediate allergic responses.

CONNECT Mast-**cell** / **basophil** granules → rapid changes in vessels and allergic symptoms.

Acute-phase protein

Blood proteins whose concentrations change during inflammation, largely because the liver changes their production. CRP and fibrinogen increase; they are useful parts of defence and indicators of an inflammatory response.

CONNECT **IL-6** → liver changes **protein** production; **CRP** and **fibrinogen** increase.

CRP

C-reactive protein: an acute-phase protein made mainly by the liver. It binds certain microbial or damaged-cell surfaces and can help activate complement; a raised blood level indicates inflammation but not its exact cause.

CONNECT C-reactive **protein**: inflammation marker; binds targets and can support opsonisation / **complement**.

14 Killing molecules and soluble defence proteins (continued)

Serum amyloid A

A blood protein whose production rises during inflammation, largely in the liver. It is one of the acute-phase proteins, a group whose levels change as part of the inflammatory response.

CONNECT Another liver-derived **acute-phase protein**; rises with inflammation.

Fibrinogen

A soluble protein in blood plasma that is converted into fibrin during clot formation. It also increases during inflammation as an acute-phase protein.

CONNECT Acute-phase and clotting **protein**; converted into fibrin, not an **antibody**.

Prothrombin / factor II

An inactive blood-clotting protein, also called factor II. During coagulation it is converted into thrombin, which converts fibrinogen into fibrin.

CONNECT Precursor → thrombin → **fibrinogen** becomes fibrin. Clotting is not haemagglutination.

Thrombin / fibrin

Thrombin is the active enzyme produced from prothrombin. It cuts fibrinogen to generate fibrin, which forms a clotting mesh. Neither is a red-cell-clumping antibody.

CONNECT Thrombin is the **enzyme**; fibrin is the structural mesh of the clot.

Insulin

A hormone made by the pancreas that helps regulate blood glucose, the sugar used for energy. It is a protein but not an antibody or a general marker of acquired immunity.

CONNECT A hormone used as a distractor; not an **antibody** or typical acquired-immunity marker.

Acetylcholine

A small neurotransmitter released at certain nerve connections. It transmits a signal by binding receptors, but it is not a protein cytokine such as IL-2.

CONNECT An example of a neural messenger rather than **cytokine** signalling.

gp91phox / NOX2

The catalytic membrane component of the phagocyte NADPH oxidase that transfers electrons to oxygen.

CONNECT Combines with **p22phox** and recruited cytosolic partners to generate superoxide.

14 Killing molecules and soluble defence proteins (continued)

p22phox

A membrane partner that stabilises the NOX2-containing part of phagocyte NADPH oxidase.

CONNECT The membrane pair recruits regulatory proteins during the respiratory burst.

p47phox

An organiser protein that helps assemble active NADPH oxidase at a membrane.

CONNECT Activation brings cytosolic oxidase components to the membrane **complex**.

p67phox

A regulatory protein that helps activate the electron-transfer activity of phagocyte NADPH oxidase.

CONNECT Works with **p47phox**, **p40phox** and **RAC2** in oxidase assembly and activity.

p40phox

A regulatory subunit involved in controlling NADPH oxidase activity, especially at phagosomal membranes.

CONNECT Part of the respiratory-burst system, not a **cytokine**.

RAC2

A small GTP-binding molecular switch used by blood cells; it participates in phagocyte NADPH oxidase activation.

CONNECT Active RAC2 helps coordinate oxidase function and other **cell** activities.

NADP+ / FAD / FADH2

Electron-carrying chemical cofactors. NADP+ is the oxidised partner of NADPH; FAD and FADH2 are oxidised and reduced forms of flavin adenine dinucleotide.

CONNECT The oxidase uses electron transfer from **NADPH** through cofactors towards oxygen.

Superoxide / oxygen

Oxygen is the gas molecule O2. Superoxide is a reactive oxygen species made when oxygen receives an extra electron.

CONNECT **NADPH oxidase** → superoxide → other reactive products, including hydrogen peroxide.

Phosphatidylserine / PS

A membrane lipid normally concentrated on the inner face of the cell membrane. Its exposure can mark dying cells for clearance.

CONNECT PS-binding and bridging proteins help phagocytes recognise apoptotic cells.

14 Killing molecules and soluble defence proteins (continued)

Annexin A1

A protein involved in limiting inflammation and supporting clearance of dying cells.

CONNECT Appears among clearance-associated proteins in the opsonisation diagram.

Protein S

A blood protein with anticoagulant functions that can also bridge exposed phosphatidylserine to receptors involved in dying-cell clearance.

CONNECT Not every clearance tag is an **antibody** or **complement** fragment.

Lactadherin / MFG-E8

A bridging protein that binds exposed phosphatidylserine on dying cells and helps phagocytes attach to them.

CONNECT PS on dying **cell** → lactadherin → **phagocyte** receptors → clearance.

Pentraxins / collectins

Families of soluble recognition proteins. CRP is a pentraxin; mannose-binding lectin is a collectin.

CONNECT Can recognise targets and support clearance or **complement** activation.

Mucin / mucus

Mucins are large sugar-rich proteins that form much of the protective gel called mucus.

CONNECT Goblet cells secrete mucins; mucus traps material and supports mucosal defence.

Glu35 / Asp52

Glutamate at position 35 and aspartate at position 52 in the classic lysozyme example. These amino-acid residues help its catalytic action.

CONNECT **Lysozyme** breaks the bond between **NAG** and **NAM** in **peptidoglycan**.

15 Microbial structures and danger molecules

PAMP = characteristic microbial pattern. DAMP = damage-associated host material. Location matters.

PAMP

Common molecular features of microbes that innate immune receptors can detect. Examples include bacterial lipopolysaccharide and viral double-stranded RNA; they are not individually generated antigen-specific receptors.

CONNECT Examples: LPS, **flagellin**, **unmethylated CpG-rich DNA** and viral **double-stranded RNA**.

DAMP

Damage-associated molecular pattern: a host-derived molecule or material that signals injury when released, misplaced or altered. It is not a microbe-specific feature.

CONNECT Extracellular **ATP** and urate crystals can signal damage rather than a microbial pattern.

LPS / lipopolysaccharide

Molecules made of lipid and sugars in the outer membrane of Gram-negative bacteria, commonly abbreviated LPS. They can strongly activate innate immune cells through a receptor system involving TLR4.

CONNECT **Gram-negative** outer membrane → **TLR4**-system signalling → innate inflammation.

Flagellin

The protein building block of many bacterial flagella, the long structures bacteria use for movement. Innate immune receptors can recognise flagellin as a sign of bacteria.

CONNECT **Protein** building block of bacterial flagella; an innate microbial-pattern clue.

Unmethylated CpG-rich DNA

CpG describes a cytosine followed by a guanine in DNA. Unmethylated means lacking a particular chemical methyl tag; certain unmethylated CpG-rich DNA patterns can alert innate receptors to microbial DNA.

CONNECT Microbial-pattern clue; not simply any **DNA** sequence.

Double-stranded RNA / dsRNA

RNA with two paired strands. It occurs in some viruses or during viral replication and can be recognised by innate immune sensors as a sign of infection.

CONNECT Often produced during viral infection → innate antiviral recognition.

15 Microbial structures and danger molecules (continued)

Single-stranded DNA / ssDNA

DNA consisting of one strand rather than the usual paired strands. Some viruses have this form; the phrase alone does not describe the particular CpG pattern tested in this question.

CONNECT Listed as a distractor in this **PAMP** question; do not infer that **DNA** sensing is impossible.

ATP

Adenosine triphosphate: a molecule cells use to transfer energy. Outside damaged cells, released ATP can act as a danger signal from the host rather than a microbe-specific PAMP.

CONNECT Adenosine triphosphate: intracellular energy carrier; extracellular ATP can signal damage.

Uric acid / urate crystals

Solid crystals that can form from uric acid, a breakdown product made by the body. They can trigger sterile inflammation, as in gout, so they are a host-derived danger signal rather than a microbial PAMP.

CONNECT Host-derived crystals → danger signalling, including **NLRP3** activation.

Peptidoglycan

A strong mesh of sugar chains linked by short amino-acid chains around many bacterial cells. It helps the bacterium keep its shape and resist bursting. Lysozyme breaks specific links in its sugar chains.

CONNECT **NAG**-**NAM** sugar chains cross-linked by peptides; a strong bacterial wall.

NAG

N-acetylglucosamine: a modified sugar that alternates with NAM in bacterial peptidoglycan chains. Lysozyme cuts the link between these repeating sugar units.

CONNECT N-acetylglucosamine alternates with **NAM** in **peptidoglycan**.

NAM

N-acetylmuramic acid: a modified sugar in bacterial peptidoglycan. It alternates with NAG and carries short amino-acid chains that help cross-link the wall into a strong mesh.

CONNECT N-acetylmuramic acid carries short **peptide** chains in the **peptidoglycan** mesh.

15 Microbial structures and danger molecules (continued)

Polysaccharide / oligosaccharide

Carbohydrate chains made of sugar units: oligosaccharides are relatively short; polysaccharides are longer. Conventional peptide-MHC-restricted T cells do not directly recognise free polysaccharide as their peptide epitope.

CONNECT Bacterial capsular polysaccharides can drive T-independent B-**cell** responses.

Bacterial capsule

A protective outer coating around some bacteria, often made of long sugar chains. It can make swallowing by immune cells harder. Antibodies against the capsule help tag the bacterium for removal.

CONNECT Can impede phagocytosis; **antibody** and **complement** coating improve clearance.

Bacterial toxin

A harmful substance made by an organism, such as a bacterial protein that damages host cells. Toxin-producing bacteria release such substances; antibodies can neutralise a toxin by blocking its action.

CONNECT Antibodies can neutralise toxins before they bind or damage their targets.

Gram-negative bacterium

Bacteria with a thin peptidoglycan wall and an additional outer membrane containing lipopolysaccharide. They stain pink/red in the Gram test. Their outer membrane can be a target for complement's membrane-damaging complex.

CONNECT Outer membrane contains LPS; some are susceptible to **MAC**-mediated lysis.

Gram-positive bacterium

Bacteria with a thick peptidoglycan wall and no Gram-negative-style outer membrane. They stain purple in the Gram test. The thick wall generally protects them against direct lysis by complement's membrane attack complex.

CONNECT Thick **peptidoglycan** wall; **lysozyme** attacks wall bonds, **MAC** generally less effective.

Streptococcus pneumoniae

A bacterial species, often called pneumococcus, that can cause pneumonia, meningitis and other infections. Its capsule helps it avoid being swallowed, so antibodies and complement are important for defence.

CONNECT Encapsulated bacterial example: **antibody**-mediated opsonisation matters.

15 Microbial structures and danger molecules (continued)

Haemophilus influenzae

A bacterial species that can cause airway and sometimes invasive infections. It is not the influenza virus. Some strains have a capsule, making antibodies against that coating important for protection.

CONNECT A bacterium, not influenza **virus**. Encapsulated strains are important in **antibody** deficiency.

Virus

An infectious particle containing genetic material inside a protein coat, sometimes with an outer membrane. It enters a living cell and uses the cell's machinery to make more virus.

CONNECT Type I IFNs resist replication; antibodies block extracellular virus; CTLs target infected cells.

Fungus

Organisms including yeasts and moulds. Some can cause infections, especially when immune defences are weakened.

CONNECT Neutrophils and **Th17** / **ILC3** barrier responses are important against many fungi.

Helminth

A parasitic worm. Because it is usually too large for a single immune cell to swallow, defence uses mechanisms such as eosinophils, mucus and type-2 immune responses.

CONNECT Large parasitic worm → **Th2** / **ILC2**, eosinophils, **IgE** and mucus-based responses.

Iron

A chemical element needed for processes such as oxygen transport and microbial growth. Keeping free iron scarce is one way the body can make it harder for microbes to multiply.

CONNECT Essential nutrient for many microbes; sequestration limits availability.

Mannose / mannan

Mannose is a sugar; mannans are sugar chains rich in mannose, found in structures such as fungal cell walls.

CONNECT Recognised by some carbohydrate-binding receptors and soluble lectins.

Beta-glucan

A glucose-based polysaccharide present in many fungal cell walls.

CONNECT **Dectin-1** can detect beta-glucan and support antifungal immune responses.

15 Microbial structures and danger molecules (continued)

Candida

A genus of yeasts, which are fungi. Some normally inhabit human surfaces but can cause infection when barriers or immune control fail.

CONNECT **Th17** responses and phagocytes are important in defence.

Giardia lamblia / trophozoite

An intestinal single-celled parasite, also called Giardia duodenalis. A trophozoite is its active, feeding form.

CONNECT Mucosal **antibody** defects can increase susceptibility to persistent giardiasis.

Microbiota / biofilm

Microbiota are the organisms living in a particular environment. A biofilm is a surface-associated microbial community in a protective matrix.

CONNECT Microbiota are not automatically pathogens; location and host conditions matter.

16 Laboratory targets, reagents and readouts

Target = analyte. Catching tool = antibody. Measurable tag = label. Calibrator = known amount.

Analyte

The substance that a test is trying to detect or measure. In a blood test for a hormone, that hormone is the analyte.

CONNECT The substance being measured; it might be an **antigen**, **antibody** or hormone.

Calibrator / standard

A sample with a known amount of the measured substance. Standards establish how the assay signal relates to concentration. They are not the same as a separate quality-control sample used to check performance.

CONNECT Known **analyte** concentration → signal-to-concentration reference.

Reagent

A prepared chemical or biological substance used to carry out a test. Antibodies, labelled molecules and enzyme substrates are examples.

CONNECT Prepared **antibody**, labelled **antigen**, **enzyme** substrate or other substance used by a test.

16 Laboratory targets, reagents and readouts (continued)

Capture / detection antibody

Names for the job an antibody has in an assay. A capture antibody retains the target; a detection antibody binds the target to support signal production. The exact arrangement depends on the assay format.

CONNECT Capture binds a target to a surface; detection helps make its presence measurable.

Label / labelled antigen

A detectable tag attached to a test reagent. An enzyme label generates a measurable product; other labels may produce light or emit radiation, making otherwise invisible antibody-antigen binding measurable.

CONNECT **Enzyme**, fluorescent tag or radioisotope makes binding measurable.

Enzyme label + chromogenic substrate

A substance an enzyme converts into a coloured product. The amount of colour can be measured as the test signal; chromogenic literally means colour-producing.

CONNECT After binding and washing, **enzyme** converts substrate → coloured product; used in colorimetric **ELISA**.

Radioisotope label

Unstable forms of chemical elements that emit radiation as they decay. If used as labels, the emitted radiation provides a measurable signal.

CONNECT Radiation from the attached **label** is detected; an **enzyme** is not required.

Fluorescent label

Light emitted by a molecule after it absorbs light of a suitable wavelength. A fluorescent label makes its attached target detectable by an instrument.

CONNECT Light excitation → emitted light; time-resolved detection reduces short-lived background.

Chemiluminescent reagents / ECL

Chemiluminescence is light produced by a chemical reaction. Here ECL means enhanced chemiluminescence: reagents strengthen the light signal so small amounts of labelled material can be detected. In some other platforms ECL means electrochemiluminescence.

CONNECT Chemical reaction → light; ECL means enhanced chemiluminescence in this deck.

16 Laboratory targets, reagents and readouts (continued)

Solid support

A surface, such as a plastic well or bead, that holds one test component in place. This allows unbound material to be washed away while bound material stays attached.

CONNECT Plastic well or bead holds components while unbound **reagent** is washed away.

Gel / precipitin complex

A jelly-like material with a network that holds liquid. In immunodiffusion tests, antigen and antibody spread through a gel and may form visible lines where they combine in suitable proportions.

CONNECT **Antigen**-**antibody** networks form visible lines or rings in immunodiffusion.

Erythrocyte surface antigens

Molecules on red blood cells that define blood groups, such as A, B and RhD. Antibodies can recognise them and produce visible haemagglutination. This is not the fibrin-based clotting process.

CONNECT Known **antibody** + matching red-**cell antigen** → clumping for blood-group typing.

ELISA

Enzyme-linked immunosorbent assay: an antibody-based test using an enzyme label and usually a solid surface such as a plastic well. After binding and washing, a substrate is added to create a measurable signal.

CONNECT **Enzyme**-linked immunosorbent assay. Competitive format often gives less signal when sample **analyte** increases.

Immune precipitate / nephelometry

Measuring light scattered by particles in a liquid. In immunonephelometry, antibody-antigen complexes form the particles, and their scattered light helps estimate the amount of the target.

CONNECT **Antibody**-**antigen** complexes scatter light. No **enzyme label** is needed for this principle.

Polyantigen

This is not the standard explanation of polyclonal antibodies. Polyclonal describes antibodies from several B-cell clones, not a special substance called a polyantigen.

CONNECT Distractor wording; polyclonal means many B-**cell** clones, not a special polyantigen **molecule**.

16 Laboratory targets, reagents and readouts (continued)

Anti-IgE / anti-IgA / anti-CTLA-4 antibody

An antibody named for the molecule it binds: IgE, IgA or CTLA-4, respectively.

CONNECT Anti-**CTLA-4** can block an inhibitory pathway; effects depend on the **antibody** and context, not just its name.

Sheep RBC / anti-sheep RBC antibody

Sheep red blood cells and antibodies against them, used as an indicator system in some complement-fixation tests.

CONNECT If **complement** was consumed by the test reaction, these indicator cells remain unlysed.

Cardinal Red / Atlantic Blue / CoraLite Plus

Commercial fluorescent labels shown in the cell-marker diagram. CoraLite Plus 488, 647 and 750 identify different detection channels.

CONNECT The dye makes binding visible; the attached **antibody** determines which CD marker is recognised.

A, B and RhD blood-group antigens

A and B are carbohydrate features on red cells; RhD is a red-cell membrane protein antigen.

CONNECT Matching antibodies can agglutinate cells; these antigens are not **MHC** molecules.

17 Clinical connections and wording traps

Locate the broken part: antibody quantity, antibody class switching, T-cell help, or phagocyte killing.

Chronic granulomatous disease / CGD

An inherited immune disorder in which phagocytes cannot generate a normal chemical burst to kill certain swallowed bacteria and fungi. Swallowing itself can still occur. Repeated infections and organised inflammatory lumps called granulomas can result.

CONNECT **NADPH oxidase** defect → reduced respiratory burst. Cells may swallow microbes but kill them poorly.

Selective IgA deficiency

Very little or no immunoglobulin A, while other major antibody classes are relatively preserved. Some people have few symptoms; others have repeated infections at moist body surfaces, such as the airways or intestine.

CONNECT Reduced mucosal **antibody** protection; many people have few or no symptoms.

17 Clinical connections and wording traps (continued)

Hyper-IgM syndrome

A group of immune disorders in which changing antibody class is impaired. IgM may be normal or high while IgG and IgA are low; some forms involve failure of the CD40L helper signal.

CONNECT Some causes impair **CD40L-CD40** help → poor class switching despite preserved / raised **IgM**.

Common variable immunodeficiency / CVID

An immune disorder with low IgG and usually low IgA and/or IgM, plus poor useful antibody responses. It can cause repeated infections, especially in airways. Variable refers to differences in presentation between affected people.

CONNECT Low effective **antibody** production; recurrent bacterial respiratory infections are a common clue.

Physiological hypogammaglobulinaemia

A normal temporary fall in an infant's blood antibody level, especially IgG. Antibodies received from the mother are disappearing before the infant's own production has fully caught up. Physiological means part of normal body development.

CONNECT Maternal **IgG** declines before infant production catches up; not automatically a pathological deficiency.

Iconoclast

Not an immune-cell name. An iconoclast is a person who challenges established beliefs or, historically, destroys religious images. Here it is a distractor resembling osteoclast, a real bone-resorbing cell.

CONNECT Not an immune **cell**. **Osteoclast**, **microglia** and **Kupffer cell** are real **cell** names.

CR in the CD4 / CD8 answer

In this deck's CD4/CD8 answer, CR appears to be an incomplete reference to the T-cell receptor, TCR. CD4 and CD8 are TCR co-receptors. Elsewhere CR can mean complement receptor, so context matters.

CONNECT Read that answer as **TCR** co-receptors. In other contexts CR may mean **complement receptor**.

X-linked agammaglobulinaemia

An inherited immune deficiency, commonly caused by BTK defects, with severely reduced mature B cells and antibodies.

CONNECT Different from **selective IgA deficiency**, where the main missing **antibody** class is **IgA**.