Test 1 Essentials

199 entries. Names, jobs and connections.

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199 selected terms from the full 398-term reference. Prioritised for recurring topics and core mechanisms, not a prediction of the actual examination.

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.

Know these first

Innate vs adaptive

Innate immunity recognises shared patterns and responds rapidly. Adaptive B/T cells have diverse, specific receptors, expand matching clones and form memory. Secondary responses are usually faster and stronger.

Cells and organs

B cells mature mainly in **bone marrow**; T cells in **thymus**. **Naive** T-**cell** activation usually occurs in secondary lymphoid organs. Dendritic cells, macrophages and B cells are professional APCs. Plasma cells secrete antibodies.

Recognition

BCR binds **native antigen** directly. Conventional **TCR** recognises peptide + **MHC**: **CD4** with **MHC II**, **CD8** with **MHC I**. **MHC I** includes **beta-2 microglobulin**. **CD3** transmits the **TCR** signal.

Activation and brakes

TCR recognition + **CD28** binding B7 gives activation signals; without costimulation, **naive** T cells can become anergic or die. **CTLA-4** inhibits. B-**cell CD40** binds helper T-**cell CD40L**.

Antibody structure

One monomer has 2 identical heavy + 2 identical light chains. Variable-region CDRs bind **antigen**; Fc recruits effector mechanisms. Heavy-**chain constant region** determines isotype. V(D)J recombination creates initial diversity; somatic hypermutation changes activated B-**cell** variable regions.

Antibody classes

IgM appears first and activates **complement** well. **IgG** predominates in adult serum and crosses the placenta. **Secretory IgA** protects mucosa. **IgE** binds mast cells and participates in allergy/parasite responses. **Naive** B cells commonly carry **IgM** and **IgD**.

Cytokine essentials

IL-1/TNF: inflammation and vessel activation. **IL-6**: liver **acute-phase proteins**. **CXCL8**/IL-8: **neutrophil** recruitment. **G-CSF**: **neutrophil** production. **IL-2**: T-**cell** growth and **Treg** support. **IL-12**: NK/**Th1** and **IFN-gamma**.

Helper programmes

Th1/IFN-gamma activate macrophages against intracellular microbes. **Th2/IL-4**, **IL-5**, **IL-13** support **IgE**, eosinophils and parasite defence. **Th17/IL-17** recruit neutrophils against **fungi** and extracellular bacteria. **IL-10** and **TGF-beta** regulate responses.

Interferons and killing

IFN-alpha/beta are type I antiviral signals; **IFN-gamma** is type II. NK cells kill stressed/infected cells without a matching **TCR**; **CD16** enables recognition of **IgG**-coated targets. CTLs recognise peptide-**MHC I**. **Perforin** and granzymes support killing.

Complement

Classical: **antigen**-**antibody** complexes; lectin: microbial sugars; alternative: amplification on permissive surfaces. All converge at C3. **C3b/iC3b** tag; **C3a/C5a** promote inflammation; **C5a** recruits strongly. **C5b**-9 is **MAC**, particularly effective against susceptible **Gram-negative** bacteria.

Phagocytosis

Chemotaxis → attachment → engulfment/**phagosome** → **lysosome** fusion → killing/degradation → disposal. **IgG** and **C3b/iC3b** enhance uptake. **NADPH oxidase** generates reactive oxygen species; its defect causes CGD. **Lysozyme** attacks **peptidoglycan**; **defensins** damage microbial membranes.

Danger sensing

PAMPs are microbial patterns such as LPS, **flagellin**, **CpG**-rich DNA and dsRNA. DAMPs are damage signals such as extracellular **ATP**/urate crystals. **TLR** signals activate gene-regulating factors. **NLRP3** + **ASC** + **procaspase-1** forms the **NLRP3 inflammasome**; **caspase-1** matures **IL-1 beta** and **IL-18**.

Immunoassays

Analyte = measured substance; calibrator = known amount; **label** = measurable tag. In the competitive format tested here, more **analyte** means less signal. Monoclonal = one clone/**epitope**; polyclonal = many clones/epitopes. Affinity is binding strength at one site.

Common traps

NK is innate but lymphoid; **NKT** is a T-**cell** group. Paneth cells are epithelial, not macrophages. Fab binds **antigen**; Fc binds effector receptors. **CD40** is on B cells; **CD40L** is on activated helper T cells. **IL-6** is a **molecule**, not a **cell**.

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.

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.

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.

01 The basic pieces (continued)

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.

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.

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**.

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.

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.

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

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**.

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.

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.

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

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.

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.

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

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.

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**.

04 Tissues, supporting cells and compartments (continued)

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.

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.

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.

04 Tissues, supporting cells and compartments (continued)

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**.

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**.

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.

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**.

05 Antigen recognition and display (continued)

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**.

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.

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**.

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.

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.

06 CD markers and receptor partnerships (continued)

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.

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.

06 CD markers and receptor partnerships (continued)

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.

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.

06 CD markers and receptor partnerships (continued)

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.

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.

07 Cytokines: inflammation and recruitment (continued)

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.

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-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.

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.

09 Interferons and blood-cell growth signals (continued)

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-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.

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.

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.

10 Antibodies: classes and subclasses (continued)

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.

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.

10 Antibodies: classes and subclasses (continued)

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.

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**.

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.

11 Antibody structure and complexes (continued)

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.

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.

11 Antibody structure and complexes (continued)

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**.

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.

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.

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.

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**.

12 Complement: tag, recruit, perforate (continued)

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.

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**.

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.

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.

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**.

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.

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.

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 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).

14 Killing molecules and soluble defence proteins (continued)

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.

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.

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**.

14 Killing molecules and soluble defence proteins (continued)

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**.

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**.

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.

15 Microbial structures and danger molecules (continued)

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.

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.

15 Microbial structures and danger molecules (continued)

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.

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.

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.

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.

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.

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.

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.

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.