Stage	Location	Main input	Main output	Purpose
Glycolysis	Cytoplasm	Glucose, ATP, NAD^+, ADP	Pyruvate, ATP, NADH	Split glucose and capture small amount of energy
Pyruvate oxidation	Mitochondrial matrix	Pyruvate, CoA, NAD^+	Acetyl-CoA, CO_2, NADH	Connect glycolysis to TCA cycle
TCA cycle	Mitochondrial matrix	Acetyl-CoA, NAD^+, FAD, ADP	CO_2, NADH, $FADH_2$, ATP	Oxidise carbon and load electron carriers
ETC and chemiosmosis	Inner mitochondrial membrane	NADH, $FADH_2$, O_2, ADP	ATP, H_2O, NAD^+, FAD	Use electron flow to generate ATP

2.7 Glycolysis

Glycolysis occurs in the cytoplasm. It has an energy investment phase and an energy payoff phase. The net output per glucose is usually described as 2 pyruvate, 2 ATP and 2 NADH.

Phosphofructokinase (PFK) is a key regulatory enzyme. ATP can act as both a substrate and an allosteric inhibitor. When ATP is abundant, high ATP binds allosterically and reduces glycolytic flux.

Glycolysis is considered ancient because it occurs in the cytoplasm, does not require oxygen, and is shared across many organisms.

2.8 Pyruvate Oxidation and TCA Cycle

Pyruvate oxidation converts pyruvate into acetyl-CoA, releasing CO_2 and producing NADH. Acetyl-CoA enters the TCA cycle.

The TCA cycle releases CO_2, generates NADH and $FADH_2$, and produces a small amount of ATP or GTP. It is both a catabolic funnel and an anabolic hub: many fuels can enter it, and some intermediates can be withdrawn for biosynthesis.

2.9 ETC and Chemiosmosis

The electron transport chain is located in the inner mitochondrial membrane. NADH and $FADH_2$ donate electrons. Electrons pass through protein complexes, and the released energy pumps protons into the intermembrane space. Oxygen is the final electron acceptor and is reduced to water.

Chemiosmosis occurs when protons flow back through ATP synthase down their electrochemical gradient. This drives ATP synthesis.

NADH usually contributes more ATP than $FADH_2$ because NADH donates electrons earlier in the chain, supporting more proton pumping.

2.10 Fermentation

Fermentation allows glycolysis to continue when oxygen is unavailable or the ETC cannot run. Its key purpose is not high ATP yield; it regenerates NAD^+ from NADH so glycolysis can continue.

Human muscle cells can reduce pyruvate to lactate. Yeast can convert pyruvate to ethanol and CO_2. Fermentation differs from anaerobic respiration: anaerobic respiration still uses an ETC with a final electron acceptor other than oxygen, while fermentation does not use an ETC.

2.11 Metabolic Integration

Metabolism is a network, not a single line. Carbohydrates, fats and proteins can feed into shared pathways.

Glycerol can enter glycolysis. Fatty acids undergo beta-oxidation to form acetyl-CoA. Amino acids can enter at different points after deamination. Ammonia must be detoxified, often by conversion to urea. In humans, acetyl-CoA cannot be converted back into glucose with a net gain because carbon is lost as CO_2 through the TCA cycle.

2.12 Photosynthesis

Photosynthesis explains where much organic chemical energy originally comes from. It is not simply respiration in reverse.

120. **How can low plasma protein cause oedema?** It lowers oncotic pressure, reducing reabsorption and allowing interstitial fluid accumulation.
121. **How can poor lymph drainage cause oedema?** Excess interstitial fluid is not returned to circulation.
122. **What does xylem transport?** Water and mineral ions, mostly upward.
123. **What creates the pull in xylem?** Transpiration generates negative pressure in the leaf.
124. **What does cohesion do in xylem?** Holds water molecules together in a continuous column.
125. **What does adhesion do in xylem?** Helps water interact with xylem walls.
126. **What does the Casparian strip do?** Blocks apoplastic entry to the stele and forces selective symplastic transport.
127. **Why is cavitation harmful?** Air bubbles break the continuous water column.
128. **What does phloem transport?** Sucrose and other organic solutes from sources to sinks.
129. **How does source loading drive phloem flow?** Sucrose lowers water potential, water enters, pressure rises and bulk flow begins.
130. **How does water stress affect phloem?** Less water enters phloem, reducing pressure flow.
131. **Why is homeostasis important?** Cells require internal conditions within functional limits.
132. **What is negative feedback?** A response that counteracts deviation from a set point.
133. **What happens after high blood glucose?** Insulin promotes glucose uptake and glycogen storage.
134. **What happens after low blood glucose?** Glucagon promotes glycogen breakdown and glucose release.
135. **Why do insulin and glucagon use surface receptors?** They are hydrophilic peptide hormones.
136. **What happens in type II diabetes?** Target cells respond poorly to insulin, reducing glucose uptake and clearance.
137. **How does ABA respond to drought?** ABA promotes stomatal closure to reduce water loss.
138. **What happens if ABA signalling fails during drought?** Stomata remain open, transpiration continues and wilting risk increases.
139. **What does blocking voltage-gated K^+ channels do?** Delays repolarisation and prolongs depolarisation.
140. **How does synaptic signalling work?** Calcium entry triggers neurotransmitter release, which binds postsynaptic receptors.
141. **How do endocrine and paracrine signalling differ?** Endocrine signals travel long distances in blood; paracrine signals act locally.
142. **What is determination?** Commitment to a cell fate.
143. **What is differentiation?** Specialisation in structure and function.
144. **What is morphogenesis?** Physical shaping of the organism.
145. **Why can the same genome produce different cell types?** Different cells express different genes.
146. **What is cleavage?** Rapid early cell divisions with little growth.
147. **How do totipotent and pluripotent cells differ?** Totipotent cells form embryonic and extraembryonic tissues; pluripotent cells form body cell types only.
148. **What are the three plant tissue systems?** Dermal, ground and vascular tissue.
149. **What are the four animal tissue types?** Epithelial, connective, muscle and nervous tissue.
150. **Why can one disease affect both gut absorption and skin barrier?** Both functions can depend on epithelial tissue.
151. **How can one mechanism link exchange, transport and homeostasis?** Exchange surfaces move substances, transport systems distribute them, and homeostatic feedback keeps internal levels functional.
152. **Why are structure-function answers stronger than definitions alone?** They explain how a physical feature produces a biological consequence.
153. **How should an unknown biological scenario be answered?** Identify the process, state the mechanism, then predict the consequence.
154. **Why do large organisms need specialised systems?** Diffusion alone is too slow across long distances, so transport and signalling systems coordinate internal cells.
155. **How do molecular and organismal biology connect?** Molecular interactions build cells, cells form tissues, and tissue-level function determines organismal performance.
156. **What makes a response exam-ready?** It uses accurate terminology, complete cause-effect logic, and a clear final consequence.

High-Yield Answer Frames

Definition Frame

```
X is ... It is important because ... This affects ...
```

Example:

```
Diffusion is the net movement of particles down a concentration gradient. It is important for exchange surfaces because cells require
```