FREE EDITION · NOTES + 3 SAMPLE MCQS

CUET · BIOLOGY · CLASS XI · CODE 304

Respiration in Plants

CUET unit: Plant Physiology → Respiration in Plants

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- Cellular respiration is the stepwise enzymatic oxidation of C–C bonds of respiratory substrates (mainly glucose) inside the cell to trap energy as ATP, the energy currency.
- Plants lack specialised respiratory organs; gas exchange is by diffusion through stomata, lenticels and loosely packed parenchyma — each plant part handles its own gas-exchange needs.
- Glycolysis (cytoplasm, EMP pathway) partially oxidises glucose to 2 pyruvate; in anaerobes/yeast/exercising muscle the pyruvate is fermented; aerobes route it to the mitochondrion for full oxidation.
- Aerobic respiration in the mitochondrion = link reaction + Krebs' (TCA) cycle in the matrix + ETS / oxidative phosphorylation on the inner membrane, yielding a theoretical net 38 ATP per glucose.
- CUET hot zones: ATP/NADH/$FADH_2$ counting at each stage, enzyme names (hexokinase, pyruvate dehydrogenase, citrate synthase, ATP synthase), ETS complexes I–V, chemiosmosis ($4H^+$ per ATP), RQ values for carbs/fats/proteins/organic acids, amphibolic nature.

📖 Detailed Notes

2.1 Core concepts

- **Respiration defined.** The breaking of C–C bonds of complex compounds through oxidation within the cells, leading to the release of a considerable amount of energy, is called respiration. The compounds oxidised in the process are called **respiratory substrates**; usually carbohydrates are oxidised, but proteins, fats and even organic acids can be used as respiratory substrates under certain conditions. The energy is not released in one step but in a series of slow, stepwise reactions controlled by enzymes, and is trapped as chemical energy in the form of **ATP — the energy currency of the cell** (NCERT §12 intro, p. 154).
- **Source of food.** Green plants and cyanobacteria prepare their own food through photosynthesis, storing chemical energy in glucose, sucrose and starch; non-green plant cells, animals (herbivores/carnivores) and saprophytes (fungi) ultimately depend on photosynthesis. Photosynthesis occurs in chloroplasts; respiration

(breakdown of complex molecules) takes place in the **cytoplasm and the mitochondria** in eukaryotes (NCERT §12 intro, p. 154).

- **Why plants need no respiratory organs.** Plants have **no specialised organs for gaseous exchange** but use **stomata** and **lenticels**. Three reasons NCERT gives: (i) each plant part takes care of its own gas-exchange needs with little transport of gases between parts; (ii) plants do not present great demands for gas exchange — roots, stems and leaves respire at rates far lower than animals; (iii) the diffusion distance is small because each living cell is close to the surface, helped further by loose packing of parenchyma that creates an interconnected network of air spaces. Living cells in woody stems remain organised in thin layers inside/beneath the bark, with **lenticels** as openings (NCERT §12.1, pp. 154–155).
- **Combustion vs respiration.** The complete combustion of glucose is $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy; in combustion most energy is given out as heat. The cell instead **oxidises glucose in small steps** so that the energy released can be coupled to ATP synthesis (NCERT §12.1, p. 155).
- **Anaerobic capability.** The first cells on this planet lived in an atmosphere that lacked oxygen; even today some organisms are **facultative anaerobes** and others **obligate anaerobes**. In any case, all living organisms retain the enzymatic machinery to **partially oxidise glucose without the help of oxygen** — this breakdown of glucose to pyruvic acid is called **glycolysis** (NCERT §12.1, p. 155).
- **Glycolysis — site & history.** The term glycolysis comes from Greek glycos (sugar) and lysis (splitting). The scheme was given by **Gustav Embden, Otto Meyerhof and J. Parnas** — hence the **EMP pathway**. It occurs in the **cytoplasm** of the cell in all living organisms and is the only respiratory process in anaerobic organisms. Glucose undergoes partial oxidation to form **two molecules of pyruvic acid** via a chain of ten enzyme-catalysed reactions; in plants this glucose is derived from sucrose (end-product of photosynthesis) or from storage carbohydrates. Sucrose is converted into glucose and fructose by **invertase** (NCERT §12.2, pp. 155–156).
- **Glycolysis — step-by-step.** Glucose and fructose are phosphorylated to glucose-6-phosphate by **hexokinase**; this isomerises to fructose-6-phosphate, then phosphorylates to fructose-1,6-bisphosphate. **ATP is utilised at two steps** — glucose → G-6-P and F-6-P → F-1,6-BP. Fructose-1,6-bisphosphate is split into **dihydroxyacetone phosphate (DHAP)** and **3-phosphoglyceraldehyde (PGAL)**. PGAL → 1,3-BPGA is the step where **$NADH + H^+$** is formed from NAD^+ (two redox-equivalents removed as hydrogen atoms). BPGA → 3-PGA yields ATP (substrate-level phosphorylation), and PEP → pyruvate yields a second ATP. Net per glucose: **2 ATP and 2 NADH** (NCERT §12.2, p. 156, Fig. 12.1).
- **Fates of pyruvate.** Three major ways cells handle pyruvic acid: (a) **lactic acid fermentation**, (b) **alcoholic fermentation** and (c) **aerobic respiration**. Fermentation occurs under anaerobic conditions in many prokaryotes and unicellular eukaryotes; complete oxidation of glucose to CO_2 and H_2O requires Krebs' cycle and O_2 (NCERT §12.2 end / §12.3, p. 157).

- **Alcoholic fermentation (yeast).** Pyruvate → CO_2 + ethanol under anaerobic conditions, catalysed by **pyruvic acid decarboxylase** and **alcohol dehydrogenase**. Yeasts poison themselves to death when ethanol reaches **~13 per cent**, which limits naturally fermented alcohol; higher-strength beverages are obtained by distillation (NCERT §12.3, p. 157).
- **Lactic acid fermentation.** Some bacteria produce lactic acid from pyruvate; in animal/muscle cells during exercise, when O_2 is inadequate, pyruvic acid is reduced to lactic acid by **lactate dehydrogenase**. NADH + H^+ is the reducing agent and is reoxidised to NAD^+ in **both** fermentations (NCERT §12.3, p. 157, Fig. 12.2).
- **Why fermentation is inefficient.** Less than **7 per cent** of the energy in glucose is released, and not all of it is trapped as high-energy bonds of ATP; further, alcohol or acid is hazardous. NADH is oxidised slowly in fermentation but vigorously in aerobic respiration (NCERT §12.3 / §12.5).
- **Aerobic respiration — two crucial events.** In eukaryotes, the final product of glycolysis (pyruvate) is transported into the **mitochondria**. The crucial events are: (i) **complete oxidation of pyruvate** by stepwise removal of all hydrogen atoms, leaving three CO_2 molecules; (ii) **passing of electrons** removed (as part of the hydrogen atoms) onto **molecular O_2** with simultaneous synthesis of ATP. The first event takes place in the **matrix** of the mitochondrion; the second on the **inner membrane** (NCERT §12.4, p. 158).
- **Link reaction (oxidative decarboxylation of pyruvate).** In the matrix, **pyruvic acid + CoA + NAD^+ → Acetyl-CoA + CO_2 + NADH + H^+**, catalysed by the **pyruvate dehydrogenase** complex requiring several coenzymes including NAD^+, Mg^{2+} and Coenzyme A. **Two NADH** are produced per glucose (one per pyruvate) (NCERT §12.4, p. 158).
- **Krebs'/TCA cycle — opening.** Acetyl-CoA enters a cyclic pathway, the **tricarboxylic acid cycle**, named after Hans Krebs who first elucidated it. The TCA cycle starts with the **condensation of the acetyl group with oxaloacetic acid (OAA) and water to yield citric acid (6C)** — catalysed by **citrate synthase** with release of CoA. Citrate is then isomerised to **isocitrate**, followed by two successive decarboxylations leading to **α-ketoglutaric acid (5C)** and then **succinyl-CoA (4C)** (NCERT §12.4.1, pp. 158–159).
- **Krebs cycle — energy harvest.** During conversion of succinyl-CoA to succinic acid, **a molecule of GTP is synthesised by substrate-level phosphorylation**; in a coupled reaction GTP is converted to GDP with simultaneous synthesis of ATP from ADP. There are **three points where NAD^+ is reduced to NADH + H^+** (at α-ketoglutarate, succinyl-CoA formation, and malate → OAA) and **one point where FAD^+ is reduced to $FADH_2$** (at succinate → fumarate). Continued oxidation of acetyl-CoA needs continued replenishment of OAA plus regeneration of NAD^+ and FAD^+ from NADH and $FADH_2$. **Summary per pyruvate: Pyruvic acid + 4 NAD^+ + FAD^+ + 2 H_2O + ADP + Pi → 3 CO_2 + 4 NADH + 4 H^+ + $FADH_2$ + ATP** (NCERT §12.4.1, p. 159, Fig. 12.3).

- **Pre-ETS audit per glucose.** Glucose has now been broken down to release CO_2 and **eight molecules of NADH + H^+** and **two of $FADH_2$** synthesised, besides just two ATP from the TCA cycle (NCERT §12.4.1, p. 159).
- **ETS location and carriers.** The **electron transport system (ETS)** is present in the **inner mitochondrial membrane**. Electrons from NADH produced in the mitochondrial matrix are oxidised by **NADH dehydrogenase (Complex I)** and transferred to **ubiquinone (UQ)** located within the inner membrane. Ubiquinone also receives reducing equivalents via **$FADH_2$ (Complex II — succinate dehydrogenase)** generated during succinate → fumarate. Reduced ubiquinone (**ubiquinol, UQH_2**) is then oxidised with transfer of electrons to **cytochrome c** via **cytochrome bc_1 complex (Complex III)**. **Cytochrome c** is a small protein attached to the outer surface of the inner membrane and acts as a **mobile carrier** between Complex III and Complex IV. **Complex IV** is the **cytochrome c oxidase** complex containing cytochromes **a and a_3** and **two copper centres** (NCERT §12.4.2, pp. 159–160, Fig. 12.4).
- **Oxidative phosphorylation & ATP yields.** Electron passage through Complexes I to IV is **coupled to ATP synthase (Complex V)** for ATP production from ADP and inorganic phosphate. **Oxidation of one NADH gives rise to 3 ATP**; oxidation of one **$FADH_2$ produces 2 ATP**. O_2 is the **final hydrogen acceptor** only at the terminal step but is vital because it drives the whole process by removing hydrogen from the system. The energy of oxidation–reduction (not light) drives ATP formation; hence the name **oxidative phosphorylation** (NCERT §12.4.2, p. 160).
- **ATP synthase / chemiosmosis.** Complex V consists of **F_1** (peripheral headpiece, contains site for ATP synthesis from ADP + Pi) and **F_0** (integral channel through which protons cross the inner membrane). Passage of protons through F_0 is coupled to the catalytic site of F_1 for ATP production. **For each ATP produced, $4H^+$ pass through F_0 from the intermembrane space to the matrix down the electrochemical proton gradient** (NCERT §12.4.2, p. 161, Fig. 12.5).
- **Respiratory balance sheet — net 38 ATP.** Net gain calculations require four idealised assumptions: (i) sequential, orderly pathway functioning — glycolysis, TCA and ETS one after another; (ii) NADH synthesised in glycolysis is transferred into the mitochondria and undergoes oxidative phosphorylation; (iii) none of the intermediates is utilised to synthesise any other compound; (iv) only glucose is being respired — no other substrate enters at intermediate stages. Under these assumptions there is a **net gain of 38 ATP molecules** during aerobic respiration of one molecule of glucose (NCERT §12.5, p. 161).
- **Fermentation vs aerobic — three differences.** (a) Fermentation = partial breakdown; aerobic = complete to CO_2 and H_2O. (b) Fermentation = net 2 ATP per glucose; aerobic = many more. (c) NADH is reoxidised slowly in fermentation, very vigorously in aerobic respiration (NCERT §12.5, p. 162).
- **Amphibolic pathway.** Glucose is the favoured substrate; all carbohydrates are first converted into glucose. **Fats** are broken into glycerol + fatty acids first; fatty acids

degrade to acetyl-CoA and enter the pathway; glycerol enters as PGAL. **Proteins** are degraded by proteases and individual amino acids (after deamination) enter at pyruvate, acetyl-CoA, or various Krebs intermediates depending on structure. Since the same intermediates are also withdrawn for biosynthesis of fatty acids and amino acids, the respiratory pathway is involved in **both catabolism and anabolism** and is best called an **amphibolic pathway** rather than a purely catabolic one (NCERT §12.6, p. 162, Fig. 12.6).

- **Respiratory Quotient (RQ).** RQ = volume of CO_2 evolved / volume of O_2 consumed in respiration; it depends on the type of respiratory substrate (NCERT §12.7, p. 163).
- **RQ values.** Carbohydrates (e.g. glucose) — RQ = **1.0** because equal CO_2 and O_2 are exchanged. Fats (e.g. tripalmitin, **$2\ C_{51}H_{98}O_6 + 145\ O_2 \rightarrow 102\ CO_2 + 98\ H_2O$**) — RQ = 102/145 ≈ **0.7**. Proteins — RQ ≈ **0.9**. In living organisms substrates are usually mixed; pure proteins or fats are never used as respiratory substrates (NCERT §12.7, pp. 163–164).

2.2 Definitions to memorise

Term	Definition	Page
Cellular respiration	Mechanism of breakdown of food materials within the cell to release energy and trap it as ATP	154
Respiration	Breaking of C–C bonds of complex compounds through oxidation in cells, releasing energy trapped as ATP	154
Respiratory substrates	Compounds oxidised during respiration — carbohydrates, proteins, fats, organic acids	154
ATP	Energy currency of the cell — chemical energy used for cellular processes	154
Stomata	Pores on leaf/stem surface allowing gas exchange in plants	154
Lenticels	Openings in the bark of woody stems for gas exchange	155
Glycolysis	Partial oxidation of glucose to 2 pyruvic acid in the cytoplasm through 10 enzyme-catalysed steps (EMP pathway)	155–156
EMP pathway	Glycolysis scheme by Embden, Meyerhof and Parnas	155
Hexokinase	Enzyme phosphorylating glucose/fructose to G-6-P / F-6-P	156
Invertase	Enzyme that splits sucrose to glucose and fructose	156
Fermentation	Incomplete oxidation of glucose anaerobically producing ethanol+CO_2 or lactic acid	157
Pyruvic acid decarboxylase	Enzyme in alcoholic fermentation converting pyruvate to acetaldehyde + CO_2	157
Alcohol dehydrogenase	Enzyme reducing acetaldehyde to ethanol in yeast	157

Term	Definition	Page
Lactate dehydrogenase	Enzyme reducing pyruvate to lactic acid in muscle/bacteria	157
Aerobic respiration	Complete oxidation of organic substances in presence of O_2 to CO_2 + H_2O + ATP	158
Pyruvate dehydrogenase	Enzyme complex catalysing oxidative decarboxylation of pyruvate to acetyl-CoA	158
Acetyl-CoA	2C molecule entering the TCA cycle by condensing with OAA	158
Tricarboxylic acid (Krebs') cycle	Cyclic matrix pathway starting with citrate from acetyl-CoA + OAA; yields 3 NADH + 1 $FADH_2$ + 1 ATP + 2 CO_2 per acetyl-CoA	158–159
Citrate synthase	Enzyme catalysing condensation of acetyl-CoA + OAA + H_2O → citric acid	158
Substrate-level phosphorylation	Direct synthesis of GTP/ATP coupled to a substrate conversion (succinyl-CoA → succinate)	159
Electron Transport System (ETS)	Chain of carriers in inner mitochondrial membrane passing electrons from NADH/$FADH_2$ to O_2 coupled to ATP synthesis	159–160
Ubiquinone (UQ)	Mobile lipid-soluble electron carrier in the inner membrane	160
Cytochrome c	Mobile protein carrier between Complex III and Complex IV	160
Oxidative phosphorylation	ATP synthesis driven by ETS oxidation–reduction energy with O_2 as final acceptor	160
ATP synthase (Complex V)	F_0–F_1 complex synthesising ATP from ADP + Pi using a proton gradient ($4H^+$/ATP)	161
Amphibolic pathway	Pathway functioning in both catabolism and anabolism — fits respiration	162
Respiratory Quotient (RQ)	Ratio of volume of CO_2 evolved to volume of O_2 consumed; depends on substrate	163

2.3 Diagrams / processes to remember

- **Fig. 12.1, p. 156 — Steps of glycolysis.** Glucose (6C) → G-6-P → F-6-P → F-1,6-BP → splits into DHAP + PGAL (3C each) → 1,3-BPGA → 3-PGA → 2-PG → PEP → pyruvate (3C). ATP used at steps 1 (hexokinase) and 3 (PFK). NADH+H^+ formed at PGAL → BPGA. ATP produced at BPGA → 3-PGA and at PEP → pyruvate. Net: 2 ATP and 2 NADH per glucose; H_2O is released at the 2-PG → PEP step (enolase).
- **Fig. 12.2, p. 157 — Anaerobic respiration.** Glucose → PGAL → 3-PGA → PEP → pyruvate (with NADH+H^+ generated). Pyruvate branches: (i) to lactic acid (NADH → NAD^+ via lactate dehydrogenase) or (ii) to ethanol + CO_2 (NADH → NAD^+ via pyruvic

acid decarboxylase + alcohol dehydrogenase). The reducing agent NADH is reoxidised to NAD^+ in both pathways.

- **Fig. 12.3, p. 159 — Citric acid cycle.** Pyruvate (3C) + NAD^+ + CoA → Acetyl-CoA (2C) + CO_2 + NADH+H^+. Acetyl-CoA + OAA (4C) → Citric acid (6C) → α-ketoglutaric acid (5C) [CO_2 + NADH+H^+] → Succinyl-CoA (4C) [CO_2 + NADH+H^+] → Succinic acid (4C) [GTP] → Fumaric → Malic → OAA [$FADH_2$ released at succinate → fumarate; NADH at malate → OAA].
- **Fig. 12.4, p. 160 — ETS.** Inner mitochondrial membrane showing intermembrane space (left), inner membrane (centre, with proton arrows $4H^+$ at Complex I, $4H^+$ at Complex III, $2H^+$ at Complex IV) and matrix (right). NADH+H^+ → Complex I (FMN, Fe–S clusters) → UQ; $FADH_2$ from succinate → fumarate enters via Complex II (Fe–S, FAD) → UQ. UQH_2 → Complex III (cytochrome bc_1, cyt b, Fe-S, cyt c_1) → cytochrome c (mobile) → Complex IV (Cyt a-Cyt a_3-Cu_A/Cu_B) → ½O_2 + $2H^+$ → H_2O. ATP synthase shown with F_0 embedded and F_1 projecting into matrix; ADP + Pi → ATP, with electrochemical gradient noted.
- **Fig. 12.5, p. 161 — ATP synthase.** F_0 channel embedded in inner membrane (outer side ↔ matrix); F_1 headpiece projecting into matrix; $4H^+$ flow inward through F_0 per ATP synthesised from ADP + Pi.
- **Fig. 12.6, p. 163 — Amphibolic interrelationships.** Three substrate boxes at top — Fats, Carbohydrates, Proteins — feed in: fats → fatty acids and glycerol; carbohydrates → simple sugars (e.g. glucose) → G-6-P → F-1,6-BP → DHAP ⇌ PGAL → pyruvic acid → acetyl-CoA → Krebs' cycle → CO_2 + H_2O; proteins → amino acids enter at pyruvic acid / acetyl-CoA / Krebs intermediates.

2.4 Common confusions / NTA trap points

- **2 vs 4 ATP in glycolysis.** Four ATP are synthesised (at BPGA → 3-PGA ×2 and PEP → pyruvate ×2) but two are consumed at the start (hexokinase and PFK steps), so the **net** gain is **2 ATP**. NTA loves to ask "net" vs "gross."
- **GTP vs ATP in Krebs.** Substrate-level phosphorylation in the cycle produces **GTP** at succinyl-CoA → succinic acid; GTP is then converted to ATP in a coupled reaction — both phrasings are correct, but the direct product is GTP.
- **NADH = 3 ATP, $FADH_2$ = 2 ATP.** This is the NCERT-stated ratio; do not use 2.5/1.5 values from outside sources for CUET.
- **Site confusion.** Glycolysis — **cytoplasm**; link reaction + Krebs — **mitochondrial matrix**; ETS + ATP synthase — **inner mitochondrial membrane**. Cytochrome c sits on the **outer surface of the inner** membrane (not in the intermembrane space proper).
- **38 ATP is theoretical.** NCERT explicitly calls it an idealised number based on **four assumptions**; questions may quote either "38 ATP" or values like ~36 ATP — pick the one matching the assumptions stated.

- **RQ trap.** Carbs = 1.0, fats ≈ 0.7, proteins ≈ 0.9. NCERT gives only the tripalmitin worked example (102/145 = 0.7) — match the exact arithmetic if numbers are given.
- **Complex II does not pump protons.** Only Complexes I, III and IV pump protons; that is why **$FADH_2$ (which enters at II) yields fewer ATP than NADH**.
- **Alcohol limit in fermentation.** Yeasts poison themselves at **~13 per cent ethanol** — natural fermented beverages cannot exceed this; higher strengths are obtained by **distillation**.
- **Glycolysis is universal.** Glycolysis occurs in **all living organisms** — not only in anaerobes; in anaerobes it is the only respiratory process.
- **Pyruvate fates are three.** Lactic acid fermentation, alcoholic fermentation, aerobic respiration — not two.
- **Cytochrome c is not free in cytoplasm.** It is a small protein **attached to the outer surface of the inner mitochondrial membrane**.
- **Final acceptor is O_2.** Oxygen acts as the **final hydrogen/electron acceptor** at Complex IV; role is "limited to the terminal stage" but drives the whole process.

2.5 Key processes / classifications

#	Stage	Site	Inputs	Outputs (per glucose / unit)	Notes / Page
1	Glycolysis (EMP)	Cytoplasm	1 glucose, 2 ATP, 2 NAD^+	2 pyruvate + 4 ATP gross (net 2) + 2 NADH	All living cells; p. 155–156
2	ATP-use step 1	Cytoplasm	Glucose + ATP, hexokinase	G-6-P	p. 156
3	ATP-use step 2	Cytoplasm	F-6-P + ATP, PFK	F-1,6-BP	p. 156
4	NADH-forming step	Cytoplasm	PGAL + NAD^+ + Pi	1,3-BPGA + $NADH+H^+$	p. 156
5	Substrate-level ATP 1	Cytoplasm	1,3-BPGA → 3-PGA	ATP	p. 156
6	Substrate-level ATP 2	Cytoplasm	PEP → pyruvate	ATP	p. 156
7	Alcoholic fermentation	Cytoplasm (yeast)	2 pyruvate, 2 NADH	2 ethanol + 2 CO_2 + 2 NAD^+	Pyruvic acid decarboxylase + alcohol dehydrogenase; p. 157
8					

#	Stage	Site	Inputs	Outputs (per glucose / unit)	Notes / Page
	Lactic acid fermentation	Cytoplasm (muscle/ bacteria)	2 pyruvate, 2 NADH	2 lactic acid + 2 NAD^+	Lactate dehydrogenase; p. 157
9	Link reaction	Mitochondrial matrix	Pyruvate + CoA + NAD^+	Acetyl-CoA + CO_2 + NADH	Pyruvate dehydrogenase, Mg^{2+}; p. 158
10	Citrate formation	Matrix	Acetyl-CoA + OAA + H_2O	Citric acid (6C) + CoA	Citrate synthase; p. 158
11	α-KG formation	Matrix	Isocitrate + NAD^+	α-KG (5C) + CO_2 + NADH	p. 158
12	Succinyl-CoA formation	Matrix	α-KG + NAD^+ + CoA	Succinyl-CoA (4C) + CO_2 + NADH	p. 159
13	Substrate-level GTP	Matrix	Succinyl-CoA → succinate	GTP → ATP	p. 159
14	$FADH_2$ point	Matrix	Succinate → fumarate	$FADH_2$	Complex II; p. 159
15	Malate → OAA	Matrix	Malate + NAD^+	OAA + NADH	p. 159
16	Complex I	Inner membrane	NADH+H^+ → UQ	4 H^+ pumped	NADH dehydrogenase, FMN, Fe-S; p. 160
17	Complex II	Inner membrane	Succinate → fumarate	$FADH_2$ → UQ; no H^+ pump	Succinate dehydrogenase; p. 160
18	Complex III	Inner membrane	UQH_2 → cyt c	4 H^+ pumped	Cytochrome bc_1; p. 160
19	Complex IV	Inner membrane	Cyt c → ½O_2 → H_2O	2 H^+ used; H_2O formed	Cyt a, a_3, two Cu centres; p. 160
20	Complex V	Inner membrane	4 H^+ + ADP + Pi	ATP	F_0/F_1; p. 161
21	ATP yield per NADH	Inner membrane	1 NADH	3 ATP	p. 160
22	ATP yield per $FADH_2$	Inner membrane	1 $FADH_2$	2 ATP	p. 160
23	Net glucose yield	Whole cell	1 glucose + O_2	Net 38 ATP	Theoretical, 4 assumptions; p. 161

#	Stage	Site	Inputs	Outputs (per glucose / unit)	Notes / Page
24	RQ — carbs	—	$C_6H_{12}O_6$ + 6 O_2	6 CO_2 + 6 H_2O; RQ = 1.0	p. 164
25	RQ — fats (tripalmitin)	—	2 $C_{51}H_{98}O_6$ + 145 O_2	102 CO_2 + 98 H_2O; RQ ≈ 0.7	p. 164
26	RQ — proteins	—	Mixed	≈ 0.9	p. 164

🎯 Practice MCQs

Q1. The scheme of glycolysis (EMP pathway) was given by:

A. Hans Krebs, Embden and Meyerhof

B. Gustav Embden, Otto Meyerhof and J. Parnas

C. Calvin, Embden and Parnas

D. Hans Krebs, Otto Meyerhof and Calvin

Q2. During glycolysis, the net gain of ATP and NADH per molecule of glucose, respectively, is:

A. 4 ATP and 2 NADH

B. 2 ATP and 4 NADH

C. 2 ATP and 2 NADH

D. 8 ATP and 2 NADH

Q3. The enzyme that catalyses the conversion of glucose to glucose-6-phosphate at the start of glycolysis is:

A. Invertase

B. Hexokinase

C. Phosphofructokinase

D. Aldolase

📊 PYQ Alignment

Respiration in Plants is among the highest-scoring chapters for CUET Biology, typically generating 8–12 MCQs per year across CUET 2023–25 cycles. Question types are dominated by numerical bookkeeping (ATP/NADH/$FADH_2$ counts per stage, net 38 ATP), enzyme identification (hexokinase, pyruvate decarboxylase, citrate synthase, ATP synthase), site/complex matching for ETS (I to V), and RQ-value MCQs for different substrates; assertion–reason items frequently target the amphibolic-pathway concept and the role of O_2 as terminal electron acceptor.

Respiration in Plants appeared in CUET (UG) Biology across 3 cycle(s) — 4 question(s) total. The questions below were extracted from official CUET (UG) papers and matched to this chapter by topic. See `/pyq/biology` for the full PYQ archive.

CUET 2023 — Actual PYQs from this chapter

Q.25 (CUET 2023) The large holes in Swiss cheese are due to:

- A) Production of oxygen
- B) Citric acid
- C) Production of carbon dioxide
- D) Ethyl alcohol

Tests: aligns with chapter content Answer: Not in extracted key — verify against official NTA key

CUET 2024 — Actual PYQs from this chapter

Q.26 (CUET 2024) Downstream processing involves:

- A) Identification
- B) Amplification
- C) Fermentation
- D) Purification

Tests: aligns with chapter content Answer: Not in extracted key — verify against official NTA key

CUET 2025 — Actual PYQs from this chapter

Q.5 (CUET 2025) Match List-I (Producer) with List-II (Acid). Producer Acid (A) Clostridium butylicum (i) Lactic acid (B) Aspergillus niger (ii) Butyric acid (C) Acetobacter aceti (iii) Citric acid (D) Lactobacillus (iv) Acetic acid

- A)
- B)
- C)
- D)

Tests: aligns with chapter content Answer: Not in extracted key — verify against official NTA key

Q.19 (CUET 2025) Match List-I (Product) with List-II (Producer). Product Producer (A) Citric acid (i) Trichoderma polysporum (B) Ethanol (ii) Monascus purpureus (C) Statins (iii) Saccharomyces cerevisiae (D) Cyclosporin -A (iv) Aspergillus niger

- A)
- B)
- C)
- D)

Tests: aligns with chapter content Answer: Not in extracted key — verify against official NTA key