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## Mitochondria

Study Guide — Cell Organelles

Pre-Med practice questions about mitochondrial structure, function, and inheritance

39 items — Study Guide with Answers

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**1 Which statement about mitochondria in eukaryotic cells is correct?**

- A** They are part of the endomembrane system and receive most of their proteins in transport vesicles from the rough ER.
- B** They contain circular DNA and 70S ribosomes similar to those of bacteria. ✓
- C** They are surrounded by a single membrane and lack their own genetic material.
- D** They are found only in animal cells and absent from plant cells.
- E** They synthesize all of the ATP produced in the cell, including that made during glycolysis.

► **Explanation:** Mitochondria have a double membrane, contain their own circular DNA and 70S ribosomes, and are thought to have arisen by endosymbiosis; they are not part of the endomembrane system and do not make all cellular ATP.



**2 In a respiring mitochondrion, where is the proton gradient that directly drives ATP synthesis by ATP synthase established?**

- A** Across the outer mitochondrial membrane, with higher  $[H^+]$  in the cytosol.
- B** Across the inner mitochondrial membrane, with higher  $[H^+]$  in the intermembrane space than in the matrix. ✓
- C** Between the mitochondrial matrix and the nucleoplasm.
- D** Across the plasma membrane, with higher  $[H^+]$  outside the cell.
- E** Within the mitochondrial matrix, with protons concentrated around mitochondrial DNA.

► **Explanation:** Electron transport pumps protons from the matrix into the intermembrane space, creating a gradient across the inner membrane that drives ATP synthase.



**3 Which process occurs primarily in the mitochondrial matrix of a eukaryotic cell?**





- A Glycolysis.
- B Citric acid (Krebs) cycle. ✓**
- C Electron transport along complexes I-IV.
- D Lactic acid fermentation.
- E Fatty acid synthesis from acetyl-CoA.

► **Explanation:** The citric acid (Krebs) cycle enzymes are located in the mitochondrial matrix; glycolysis occurs in the cytosol and the electron transport chain is in the inner membrane.

**4 A mutation in mitochondrial DNA severely reduces ATP production. Which pattern of inheritance is most consistent with this defect in humans?**



- A Affected fathers transmit the mutation to all of their children, but affected mothers do not.
- B Only male offspring can inherit the mutation.
- C All children of an affected mother can inherit the mutation, but affected fathers do not transmit it. ✓**
- D The mutation appears only when both parents are affected.
- E The mutation always skips one generation before reappearing.

► **Explanation:** Mitochondrial DNA is inherited almost exclusively from the mother, so affected mothers can pass the mutation to all offspring, whereas affected fathers do not pass it on.

**5 A chemical uncoupler of oxidative phosphorylation allows protons to move freely across the inner mitochondrial membrane. Assuming abundant substrates and oxygen are available, what is the most immediate effect on mitochondrial function?**



- A Electron transport and oxygen consumption stop completely.





**B Electron transport and oxygen consumption increase, but ATP synthesis falls sharply. ✓**

- C** Both electron transport and ATP synthesis increase.
- D** The proton gradient across the inner membrane becomes steeper than normal.
- E** The citric acid cycle stops because  $\text{NAD}^+$  is no longer regenerated.

► **Explanation:** Uncouplers dissipate the proton gradient, so the electron transport chain works faster (increasing  $\text{O}_2$  consumption) but ATP synthase cannot use the gradient to make ATP.

**6** During active respiration, how do the pH and proton concentration of the mitochondrial matrix compare to those of the intermembrane space?



- A** Matrix has lower pH and higher  $[\text{H}^+]$  than the intermembrane space.
- B Matrix has higher pH and lower  $[\text{H}^+]$  than the intermembrane space. ✓**
- C** Matrix and intermembrane space always have identical pH and  $[\text{H}^+]$ .
- D** Matrix lacks protons entirely; all protons accumulate in the cytosol.
- E** Matrix initially has lower  $[\text{H}^+]$ , but this reverses once ATP synthase begins to function.

► **Explanation:** Proton pumping makes the intermembrane space more acidic (higher  $[\text{H}^+]$ ) than the matrix, so the matrix has a relatively higher pH and lower proton concentration.

**7** A drug is added to isolated, actively respiring mitochondria supplied with abundant oxygen and substrates. The drug specifically inhibits ATP synthase (complex V) but does not directly affect complexes I–IV. Which of the following immediate responses is most likely?



- A** Proton pumping across the inner mitochondrial membrane stops while oxygen consumption sharply increases.
- B The proton gradient across the inner mitochondrial membrane increases initially, and oxygen consumption decreases. ✓**





- C** The proton gradient collapses immediately, but oxygen consumption remains unchanged.
- D** Both the proton gradient and oxygen consumption immediately increase.
- E** No change occurs because ATP synthase is not required for oxidative phosphorylation.

► **Explanation:** Complexes I–IV continue pumping protons, so the proton gradient initially becomes steeper; as back-pressure builds, electron transport slows and oxygen consumption falls because protons cannot re-enter through ATP synthase.

**8** A cultured mammalian cell line is engineered to completely lack functional mitochondria but retains all other cellular components. The cells are supplied with abundant glucose and oxygen. Which statement best describes their ATP production and metabolism of pyruvate under these conditions?



- A** They generate almost the same ATP per glucose by greatly accelerating oxidative phosphorylation in the cytosol.
- B** They cannot regenerate  $\text{NAD}^+$ , so glycolysis quickly stops and ATP production falls to zero.
- C** They rely on glycolysis followed by conversion of pyruvate to lactate to regenerate  $\text{NAD}^+$ , yielding much less ATP per glucose. ✓
- D** They shift citric acid cycle enzymes to the cytosol and maintain normal ATP yield per glucose.
- E** They switch to using peroxisomes for electron transport and ATP synthesis.

► **Explanation:** Without mitochondria, pyruvate cannot enter the citric acid cycle, so cells regenerate  $\text{NAD}^+$  by reducing pyruvate to lactate and obtain only the small ATP yield from glycolysis (substrate-level phosphorylation).

**9** A mitochondrial matrix enzyme is encoded by a nuclear gene and is normally synthesized in the cytosol with an N-terminal targeting sequence that directs it into mitochondria. A mutation removes this targeting sequence but leaves the rest of the protein unchanged. In which cellular compartment will the mutant enzyme most likely accumulate?





- A Mitochondrial matrix.
- B Mitochondrial intermembrane space.
- C Cytosol. ✓**
- D Rough endoplasmic reticulum lumen.
- E Peroxisomal matrix.

► **Explanation:** Most mitochondrial proteins are made on free cytosolic ribosomes and require a specific targeting sequence for import; without it, the protein remains soluble in the cytosol and cannot enter the mitochondrial matrix.

**10** Which mitochondrial structure contains most of the proteins of the electron transport chain and ATP synthase?



- A Outer mitochondrial membrane
- B Inner mitochondrial membrane ✓**
- C Intermembrane space
- D Mitochondrial matrix
- E Cytosol

► **Explanation:** The electron transport chain (Complexes I–IV) and ATP synthase are embedded in the INNER mitochondrial membrane, where they use the proton gradient to make ATP.

**11** Cristae in mitochondria are best described as:



- A Invaginations of the outer membrane that store calcium
- B Folds of the inner membrane that increase surface area for oxidative phosphorylation ✓**
- C Infoldings of the plasma membrane that anchor mitochondria





- D Stacks of membranes continuous with the rough ER
- E Channels connecting the matrix directly to the cytosol

► **Explanation:** Cristae are folds of the INNER membrane. They increase the membrane surface area available for the electron transport chain and ATP synthase, boosting ATP production.

**12** Which of the following human cell types would be expected to have the **HIGHEST** number of mitochondria?



- A Red blood cell
- B Cardiac muscle cell ✓**
- C Mature fat (adipose) cell storing triglycerides
- D Skin epidermal cell about to be shed
- E Bacterial cell

► **Explanation:** Cells with high continuous energy demand, such as cardiac muscle cells, are rich in mitochondria. Mammalian red blood cells have NO mitochondria.

**13** Which statement about mammalian red blood cells (RBCs) and mitochondria is **CORRECT**?



- A RBCs contain many mitochondria to support aerobic respiration
- B RBCs contain a single large mitochondrion for ATP production
- C RBCs lack mitochondria and rely mainly on glycolysis for ATP ✓**
- D RBCs contain mitochondria but do not use them
- E RBCs contain chloroplasts instead of mitochondria





► **Explanation:** Mammalian RBCs eject their nucleus and organelles, including mitochondria, and obtain ATP mainly via anaerobic glycolysis.

**14** In eukaryotic cells, the reactions of the citric acid (Krebs) cycle occur mainly in the:



- A Cytosol
- B Rough endoplasmic reticulum
- C Golgi apparatus
- D Mitochondrial matrix ✓**
- E Intermembrane space

► **Explanation:** The citric acid cycle enzymes are located in the mitochondrial matrix, where acetyl-CoA is oxidized to CO<sub>2</sub> and high-energy electron carriers are produced.

**15** Which combination of processes occurs primarily in mitochondria during aerobic respiration?



- A Glycolysis and fermentation
- B Citric acid cycle, -oxidation of fatty acids and oxidative phosphorylation ✓**
- C DNA replication and transcription of all nuclear genes
- D Protein synthesis for all cellular proteins
- E Glycolysis and DNA replication

► **Explanation:** Mitochondria host the citric acid cycle, -oxidation of fatty acids, and oxidative phosphorylation. Glycolysis occurs in the cytosol.





16 Which statement correctly describes the OUTER mitochondrial membrane?



- A It is highly impermeable to small molecules and ions
- B It contains porin channels and is relatively permeable to small molecules ✓**
- C It contains ATP synthase complexes
- D It forms cristae to increase surface area
- E It stores mitochondrial DNA

► **Explanation:** The outer membrane contains porins, making it quite permeable to small molecules. The inner membrane is highly selective and houses the ETC and ATP synthase.

17 Which feature provides strong evidence that mitochondria evolved from free-living bacteria (endosymbiotic theory)?



- A Presence of a single membrane and 80S ribosomes
- B Possession of circular DNA and 70S ribosomes ✓**
- C Ability to perform photosynthesis
- D Absence of any genetic material
- E Production of cellulose cell walls

► **Explanation:** Mitochondria have circular DNA and bacterial-like ribosomes (70S), supporting their origin from an ancestral prokaryote.

18 Which statement about mitochondrial DNA (mtDNA) is CORRECT in humans?



- A It is linear and packaged with histones like nuclear DNA





- B It is circular and inherited almost exclusively from the mother ✓**
- C It encodes all mitochondrial proteins
- D It is found only in the nucleus
- E It is present only in sperm cells

► **Explanation:** Human mtDNA is circular and maternally inherited. It encodes some, but not all, mitochondrial proteins; many are encoded by nuclear genes.

**19** A cell increases its energy demand over time (e.g., a training muscle cell). Which statement about mitochondria is **MOST** accurate?



- A The number and size of mitochondria are fixed and cannot change
- B Mitochondria can proliferate by division, increasing their number ✓**
- C Mitochondria can only be produced by the Golgi apparatus
- D Mitochondria disappear when energy demand rises
- E New mitochondria must be imported from the bloodstream

► **Explanation:** Mitochondria are dynamic and can divide (similar to bacterial fission), so cells with higher energy demands often contain more mitochondria.

**20** In oxidative phosphorylation, the proton ( $H^+$ ) gradient generated by the electron transport chain is located:



- A Across the nuclear envelope
- B Between the mitochondrial matrix and intermembrane space ✓**
- C Between the cytosol and extracellular fluid
- D Across the outer mitochondrial membrane only
- E Across the plasma membrane





► **Explanation:** The ETC pumps  $H^+$  from the matrix into the intermembrane space, creating an electrochemical gradient that drives ATP synthesis as protons flow back into the matrix via ATP synthase.

**21** An uncoupling agent makes the inner mitochondrial membrane leaky to protons. What is the MOST DIRECT effect on mitochondrial function?



- A Electron transport stops immediately
- B The proton gradient collapses and ATP production falls, with energy released mainly as heat ✓**
- C The proton gradient increases and ATP production rises
- D The citric acid cycle stops producing NADH
- E Glycolysis is directly inhibited

► **Explanation:** Uncouplers allow protons to return to the matrix without passing through ATP synthase, so the gradient is lost and oxidative phosphorylation produces less ATP but more heat.

**22** Brown adipose (fat) tissue in newborns contains many mitochondria with uncoupling protein (UCP1). Its main function is to:



- A Increase ATP production for muscle contraction
- B Generate heat by allowing protons to leak and dissipate the gradient ✓**
- C Store extra oxygen in hemoglobin
- D Carry out photosynthesis
- E Synthesize cholesterol

► **Explanation:** UCP1 in brown fat mitochondria uncouples oxidative phosphorylation, so energy from the proton gradient is released as heat rather than stored as ATP.





**23** In the mitochondrial electron transport chain, molecular oxygen ( $O_2$ ) acts mainly as:



- A The initial electron donor
- B A proton pump in Complex I
- C The final electron acceptor, forming water ✓**
- D A substrate of the citric acid cycle
- E A competitive inhibitor of ATP synthase

► **Explanation:** At Complex IV, electrons are finally transferred to  $O_2$ , which is reduced to water. Without  $O_2$ , the ETC stops and oxidative phosphorylation ceases.

**24** If oxygen supply to a cell is suddenly cut off, which mitochondrial process would be affected **FIRST**?



- A Glycolysis in the cytosol
- B Electron transport and oxidative phosphorylation ✓**
- C DNA replication in the nucleus
- D Protein synthesis on rough ER
- E All mitochondrial functions would immediately continue unaffected

► **Explanation:** The ETC directly requires  $O_2$  as final electron acceptor, so oxidative phosphorylation stops first; glycolysis can continue anaerobically for a time.

**25** Protons flow **THROUGH** ATP synthase in mitochondria from:



- A Intermembrane space into the matrix ✓**





- B Matrix into the intermembrane space
- C Cytosol into the intermembrane space
- D Nucleus into the cytosol
- E Endoplasmic reticulum into the matrix

► **Explanation:** ATP synthase uses the proton gradient between intermembrane space (high  $H^+$ ) and matrix (low  $H^+$ ); protons move down this gradient into the matrix to drive ATP formation.

**26** Which step in aerobic respiration directly links glycolysis in the cytosol to the citric acid cycle in the mitochondrion?



- A Conversion of glucose to glucose-6-phosphate
- B Conversion of pyruvate to acetyl-CoA in the mitochondrial matrix ✓
- C Formation of lactate from pyruvate
- D Binding of oxygen to hemoglobin
- E Conversion of  $CO_2$  to bicarbonate

► **Explanation:** Pyruvate produced in glycolysis enters mitochondria and is converted to acetyl-CoA, which enters the citric acid cycle.

**27** Which of the following is NOT a typical function of mitochondria?



- A ATP production via oxidative phosphorylation
- B Participation in apoptosis (programmed cell death)
- C Heat production in brown fat
- D Synthesis and modification of secreted proteins for export ✓
- E Regulation of intracellular calcium levels





► **Explanation:** Secreted proteins are synthesized and processed mainly by ribosomes on rough ER and the Golgi apparatus, not by mitochondria.

**28** In apoptosis, mitochondria can initiate cell death by releasing which molecule into the cytosol?



- A ATP synthase
- B Cytochrome c ✓**
- C Glucose
- D DNA polymerase
- E Lactate dehydrogenase

► **Explanation:** Release of cytochrome c from mitochondria into the cytosol helps activate caspases, key enzymes in programmed cell death.

**29** A woman has a disease caused by a mutation in her mitochondrial DNA. Which pattern of inheritance is most expected for her children?



- A Only her sons can inherit the disease
- B Only her daughters can inherit the disease
- C All her children (sons and daughters) may inherit the disease ✓**
- D None of her children can inherit the disease
- E Only children of her husband will inherit the disease

► **Explanation:** Mitochondria are inherited from the mother's egg. An affected mother can pass mtDNA mutations to ALL of her children, regardless of sex.





30 Which statement correctly describes the compartments of a mitochondrion?



- A The matrix lies between the outer and inner membranes
- B The intermembrane space lies between the outer and inner membranes ✓**
- C Cristae are folds of the outer membrane
- D The cytosol is another name for the mitochondrial matrix
- E The inner membrane is continuous with the nuclear envelope

► **Explanation:** The space between the outer and inner membranes is the intermembrane space; the matrix is inside the inner membrane.

31 Which process of glucose metabolism does NOT take place inside mitochondria?



- A Citric acid cycle
- B Oxidative phosphorylation
- C Conversion of pyruvate to acetyl-CoA
- D Glycolysis ✓**
- E -oxidation of fatty acids

► **Explanation:** Glycolysis occurs in the cytosol, not in mitochondria. The citric acid cycle, oxidative phosphorylation and pyruvate dehydrogenase are mitochondrial.

32 Which statement about mitochondrial replication is MOST accurate?



- A Mitochondria are formed de novo from the plasma membrane
- B Mitochondria divide by a process resembling bacterial binary fission ✓**





- C Mitochondria can only replicate during S phase with nuclear DNA
- D Each cell synthesizes mitochondria from free lipids and proteins in the cytosol
- E Mitochondria can be synthesized only in the Golgi apparatus

► **Explanation:** Mitochondria are semi-autonomous and replicate by growth and division similar to bacterial fission, independent of the cell cycle phase.

**33** Which of the following tissues would be **MOST** severely affected by a general defect in mitochondrial ATP production?



- A Cartilage in the ear
- B **Cardiac and skeletal muscle** ✓
- C Outer layer of dead skin cells
- D Mature red blood cells
- E Hair shaft keratin

► **Explanation:** Tissues with very high energy demands, such as heart and skeletal muscle, are especially sensitive to mitochondrial dysfunction.

**34** Which statement about mitochondria in **PLANT** cells is **CORRECT**?



- A Plant cells lack mitochondria because they have chloroplasts instead
- B **Plant mitochondria produce ATP by oxidative phosphorylation, just as in animal cells** ✓
- C Plant mitochondria are responsible for photosynthesis
- D Plant cells use only chloroplasts for all ATP needs
- E Plant mitochondria contain no DNA





► **Explanation:** Plant cells have BOTH chloroplasts (for photosynthesis) and mitochondria (for aerobic respiration and ATP production).

**35** Which combination correctly links mitochondrial NADH and FADH<sub>2</sub> to ATP yield in oxidative phosphorylation (assuming ideal conditions)?



- A** NADH contributes more ATP per molecule than FADH<sub>2</sub> ✓
- B** FADH<sub>2</sub> contributes more ATP per molecule than NADH
- C** Both contribute exactly the same ATP per molecule
- D** Neither NADH nor FADH<sub>2</sub> contributes electrons to the ETC
- E** Only FADH<sub>2</sub> enters the ETC

► **Explanation:** Mitochondrial NADH donates electrons to Complex I and yields slightly more ATP than FADH<sub>2</sub>, which enters at Complex II (fewer protons pumped). Exact numbers are not usually tested at pre-med level, but the relative difference is important.

**36** Which statement best explains why mitochondrial diseases often show variable severity among tissues in the same individual?



- A** Mitochondria are evenly distributed and function identically in all tissues
- B** All tissues have identical energy demands
- C** Different tissues have different energy requirements and may contain different proportions of mutant vs normal mitochondria ✓
- D** Only the liver contains mitochondria
- E** Mitochondrial DNA mutations always affect only the skin

► **Explanation:** High-energy tissues (e.g. muscle, brain) are more affected by mitochondrial defects, and the proportion of mutated mtDNA can vary between tissues (heteroplasmy).





**37** Which of the following best describes the role of mitochondria in aerobic vs anaerobic respiration?



- A** Mitochondria are essential for aerobic respiration but not required for anaerobic glycolysis ✓
- B** Mitochondria are essential for anaerobic respiration but not for aerobic
- C** Both aerobic and anaerobic ATP production occur exclusively in mitochondria
- D** Anaerobic ATP production is impossible in human cells
- E** Aerobic respiration occurs only in the cytosol

► **Explanation:** Aerobic respiration depends on mitochondrial oxidative phosphorylation. Anaerobic ATP production via glycolysis occurs in the cytosol and does not require mitochondria.

**38** Which statement about the **SELECTIVITY** of the inner mitochondrial membrane is **CORRECT**?



- A** It is freely permeable to all small ions and molecules
- B** It is highly selective and contains specific transport proteins for many metabolites ✓
- C** It contains porin channels that allow any molecule to pass
- D** It is composed mainly of cellulose
- E** It is absent in mature mitochondria

► **Explanation:** The inner membrane is very selective and requires specific transporters for ADP, ATP, pyruvate, and many other solutes. This selectivity helps maintain the proton gradient.





**39** Which of the following **BEST** explains why mitochondria are often found clustered near regions of high ATP use, such as the flagellum of a sperm cell?

- A** Mitochondria release oxygen directly into those regions
- B** Mitochondria can only function if they are attached to microtubules
- C** Localisation near high-demand regions reduces the distance ATP must diffuse to reach energy-requiring processes ✓
- D** Mitochondria are immobile and cannot change position in the cell
- E** ATP is toxic if distributed evenly in the cell

► **Explanation:** Mitochondria are mobile and often accumulate where ATP is most needed, such as near the sperm flagellum, improving the efficiency of energy delivery.

