

Electron Transport Chain Simulator

Name: _____ Period: _____ Date: _____

Open **peebedu.com** and navigate to **Electron Transport Chain Simulator**. Click the **Power Up!** button to begin. Read the introduction popup, which describes the inputs (NADH, FADH₂, O₂), the process (electron flow and proton pumping), the outputs (ATP and H₂O), and the significance of the electron transport chain.

Part 1 – Model Evaluation (MAPP Framework)

Scientific models are simplified representations of complex biological phenomena. Use the MAPP framework below to evaluate the Electron Transport Chain Simulator as a scientific model.

M – Mode

What type of model is the Electron Transport Chain Simulator? Describe how this computational simulation represents the process of oxidative phosphorylation within a mitochondrion. In your answer, identify at least three specific simulation elements (such as the electron flow animation through complexes, the H⁺ particles being pumped into the intermembrane space, the ATP synthase spinning animation, the oxygen molecules at the end of the chain, or the ATP counter) and explain what each one is designed to show about the electron transport chain.

A – Accuracy

(a) Identify two things this simulation represents **accurately** about the electron transport chain and oxidative phosphorylation. For each, name the specific simulation feature (e.g., the visible coupling between electron flow through complexes and H^+ pumping into the intermembrane space, the ATP synthase spinning only when the proton gradient is sufficient, or O_2 molecules accepting electrons and forming water at the final complex) and explain what aspect of the ETC it demonstrates.

(b) Identify two things this simulation **oversimplifies or leaves out** about the electron transport chain. Consider what you cannot observe in the simulation that would be important for a complete understanding of how electrons transfer energy through redox reactions to build a proton gradient. For example, think about whether you can see the actual chemical oxidation-reduction reactions at each complex, whether the proton counts represent real concentrations, and whether the simulation shows what happens to the cell when oxygen is completely absent.

P – Purpose

What is the learning goal of this simulation? Explain how the Electron Transport Chain Simulator is designed to help you understand how the transfer of electrons from NADH and $FADH_2$ through protein complexes is coupled to proton pumping, which creates the electrochemical gradient that drives ATP synthesis through chemiosmosis. In your answer, connect at least one specific simulation feature to the biological significance of oxidative phosphorylation for cellular energy production.

P — Permanency

Could this model change with new scientific evidence? Describe one way that new discoveries — such as structural studies revealing how ETC complexes organize into supercomplexes (respirasomes), or revised measurements of the exact number of protons pumped per electron pair — might change or improve a simulation like the Electron Transport Chain Simulator. Explain why scientific models, including computational simulations, are revised as new evidence becomes available.

Small-Group Discussion

With your group, discuss the following:

- What are the strengths of this simulation as a model for the electron transport chain and chemiosmosis?
- What are its limitations?
- If you could add one feature to improve this simulation, what would it be and why?
- How does manipulating the three sliders (temperature, electron carrier supply, and oxygen concentration) help you understand how changes in conditions affect ATP production?

Part 2 – Free Response Questions

Conceptual Analysis

Question 1 – Oxygen and the Electron Transport Chain

Simulation Task: Set the Oxygen Concentration slider to its maximum value (10) and the Electron Carrier Supply to Medium. Click Start and observe the electron flow, H^+ gradient buildup, and ATP counter for 30 seconds. Then reduce the Oxygen Concentration slider to 1 (Low) and observe what happens to electron flow, the H^+ gradient, and ATP production for another 30 seconds.

(A) (1 pt) **Describe** the changes you observe in electron flow, the H^+ gradient, and ATP production when the oxygen concentration is reduced from high to low.

(B) (1 pt) **Explain** why oxygen is essential for the electron transport chain to function, including its role as the final electron acceptor and the consequence of its absence for proton pumping and the electrochemical gradient.

(C) (1 pt) **Predict** what would happen to the rate of ATP production by oxidative phosphorylation in a muscle cell if blood flow to the muscle were temporarily reduced, limiting the oxygen supply to the mitochondria.

(D) (1 pt) **Justify** your prediction by explaining the relationship between oxygen availability, electron transport, the proton gradient, and ATP synthesis through chemiosmosis.

Analyze Model / Visual Representation

Question 2 — The Proton Gradient and Chemiosmosis

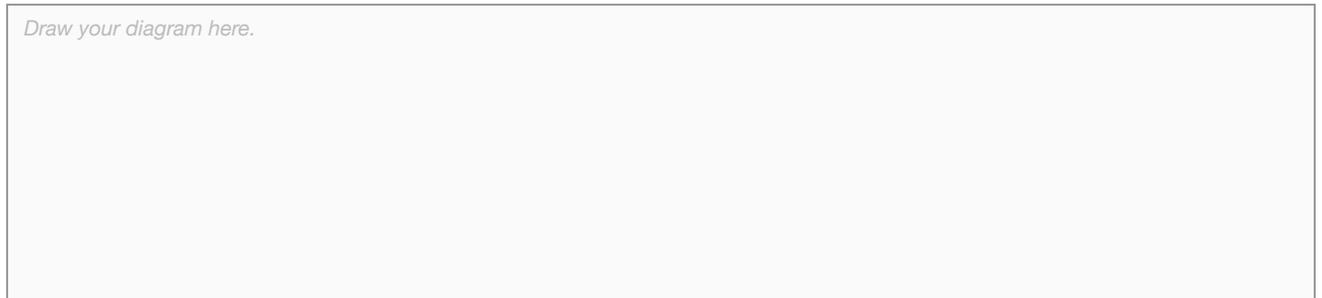
Simulation Task: Set Temperature to Normal, Electron Carrier Supply to Fast, and Oxygen Concentration to 5 (Medium). Click Start and observe for 30 seconds. Watch the H^+ particles being pumped into the intermembrane space, the gradient indicator, and the ATP synthase animation. Note when ATP synthase begins spinning and when new ATP molecules appear.

(A) (1 pt) **Describe** the relationship between the accumulation of H^+ in the intermembrane space and the activity of ATP synthase.

(B) (1 pt) **Explain** how the transfer of electrons through the protein complexes of the electron transport chain creates the electrochemical gradient that provides the energy for ATP production by ATP synthase.

(C) (1 pt) **Represent** the process of chemiosmosis in the mitochondrion.

Draw your diagram here.



(D) (1 pt) **Explain** how the dependence of ATP production on a functional electron transport chain could act as a selective pressure on organisms.

EK 3.5.A.3, 3.4.B.4