

Electron Transport Chain Karaoke: User's Guide

Introduction:

[Electron Transport Chain, Karaoke?](#) Why in the world would I bother to make such a thing? And why would I expect anyone to use it?

It's all about learning – deep, substantial, permanent learning –informed by insights emerging from cognitive science (explained in the book [Make it Stick](#)). My hypothesis is that

1. If you become familiar with my original [Electron Transport Chain Song](#), and
2. Then try to sing it yourself following the fill-in-the-blanks lyrics on the screen of the [Electron Transport Chain, Karaoke](#) then
3. Your path to memorizing the material in the song will be much more efficient than just about anything else that you can do.

That's because interacting with the song in this way is *effortful*. This is not an easy task. But if you do the hard work of trying to memorize the lyrics in this guided way, you'll learn a lot about the Electron Transport Chain. Fill-in-the-blanks karaoke is going to help you to transfer the information to where you need it: into long term memory, where it will be available for that upcoming discussion session or test.

There are, of course, alternatives to remembering this material. Flashcards are another great way that forces you to recall what you know, and thereby encodes your learning in long-term memory. I have [Electron Transport Chain flashcards](#) set up for you at my website.

Give it a try. It's going to be difficult. You won't get it right the first time. Keep on going back and forth between the fill-in-the-blank lyrics on the next page, and the original lyrics (with all the blanks filled in) that follow. Eventually, you'll be able to sing the Karaoke version fluently. And my hypothesis is that if you can do that, you'll have learned a lot about the Electron Transport Chain in a fairly permanent way.

Please leave me a comment letting me know what you think.

Electron Transport Chain Song (Karaoke, Fill-in-the-Blanks Lyrics)

View it at www.sciencemusicvideos.com

Glenn Wolkenfeld © 2015

Welcome to this story about cell _____
The goal is explaining how cells make _____
It happens in the _____ which you can think of
As the cell's _____ factory

Mitochondria are double-membraned organelles,
An inner membrane and an _____ one as well
The mitochondrial matrix is the _____ inside
It's where reactions like _____ cycle reside

_____ and Krebs make NADH
and FADH₂ from energy in _____
These _____ carriers make their way
From the _____ to the inner membrane.

And that's where you find the _____ transport _____
It's a series of _____ embedded in the membrane,
Which take the electron carrier's _____
And uses their _____ for pumping protons

CHORUS

*The _____ electron transport chain
Uses electron _____ for pumping protons
From the mitochondrial _____ to the _____ space
Increasing _____ concentration in that place,
The only way the protons can _____
Is through a _____ and an _____, ATP synthase.
Which uses diffusing protons' _____ energy
To make ATP, from _____ and P*

The chain is a _____ of enzymes in a row
Each accepts _____, then lets them go
To the next _____ in this transport chain.
It's kind of organized like a _____ brigade

What drives electrons _____ this enzymatic series
Is the growing level of each carrier's _____
And to _____ electrons ultimately fall
It's the most _____ of them all

It's NADH that starts this run
_____ electrons to _____ number 1
This powers _____ transport as protons are displaced.
And get _____ from the matrix to the intermembrane
space

From Complex I electrons _____ to
_____, also known as "Q"
Which floats through the _____ membrane happily
And brings its electrons to Complex _____

And you can guess the _____ of Complex III .
It's another _____ pump using electron energy
Protons jam up in that intermembrane _____
Like a hundred people in a one _____ apartment!

CHORUS

Complex II is for _____
Which donates electrons, which then get passed to _____
Which once again passes them to _____ III
Which _____ protons using _____ energy

From Complex III the _____ proceed
To another mobile carrier, _____ C
Which donates the electrons to Complex _____
Another _____ pump, could you ask for more?

After Complex IV _____ flow,
To _____ which is ever so
Electronegative it pulls electrons down the _____,
Keeping them _____ like the cars of a train.

And as O₂ does this electron _____ trick,
It also grabs _____ from _____ matrix.
They all combine to form H₂O
Electron _____ chain, watch it go!

CHORUS

Now all these _____ in the intermembrane space
Are _____ they can't get _____ of that place
'Cause protons are _____ and could never get through
A _____ bilayer, they can't _____

But like all _____, they're dying to go
From where their concentration's _____ to where it's low
Stuck in the intermembrane _____ they're frustrated.
To diffuse to the _____, they're highly _____.

And this _____ been made steeper by O₂
Which _____ from the matrix stew,
So from _____ pumping, and _____ actions.
Add another force, _____ attraction!

Think of all those _____ protons, each one's _____.
The matrix, in comparison is _____.
_____ attract, so the _____ are dying
To get to _____, oh how they're trying!

There's only one _____ that let's _____ pass,
And they use it like high school students busting _____ of class,
It's a _____ *and* an _____, it's ATP _____
The closer in this game, an energy ace

ATP _____ is embedded in the _____ membrane
How it works is so cool it's insane.
It's got channels for _____ running right through it.
When cells make _____, well watch how they do it

The _____ side of ATP _____ has _____ sites
For _____ and P which come in and bind.
And as ATP synthase lets _____ barge through
Their _____ energy gets put to use.

Like _____ through a turbine proton _____ generates _____.
Changing synthase's binding site _____.
Which catalyzes _____ formation.
_____ and P make _____ that energy sensation!

CHORUS

Electron Transport Chain Song (Full Lyrics)

View it at www.sciencemusicvideos.com

Glenn Wolkenfeld © 2015

Welcome to this story about cell energy
The goal is explaining how cells make ATP
It happens in the mitochondria which you can think of
As the cell's energy factory

Mitochondria are double-membraned organelles,
An inner membrane and an outer one as well
The mitochondrial matrix is the fluid inside
It's where reactions like Krebs cycle reside

Glycolysis and Krebs make NADH
and FADH₂ from energy in food
These electron carriers make their way
From the matrix to the inner membrane.

And that's where you find the electron transport chain
It's a series of enzymes embedded in the membrane,
Which take the electron carrier's electrons
And uses their energy for pumping protons

CHORUS

*The mitochondrial electron transport chain
Uses electron energy for pumping protons
From the mitochondrial matrix to the intermembrane
space
Increasing proton concentration in that place,
The only way the protons can escape
Is through a channel and an enzyme, ATP synthase.
Which uses diffusing protons' kinetic energy
To make ATP, from ADP and P*

The chain is a series of enzymes in a row
Each accepts electrons, then lets them go
To the next carrier in this transport chain.
It's kind of organized like a bucket brigade

What drives electrons down this enzymatic series
Is the growing level of each carrier's electronegativity
And to oxygen electrons ultimately fall
It's the most electronegative of them all

It's NADH that starts this run
Donating electrons to Complex number I
This powers active transport as protons are displaced.
And get pumped from the matrix to the intermembrane
space

From Complex I electrons flow to
Ubiquinone, also known as "Q"
Which floats through the inner membrane happily
And brings its electrons to Complex III

And you can guess the function of Complex III .
It's another proton pump using electron energy
Protons jam up in that intermembrane compartment
Like a hundred people in a one bedroom apartment!

CHORUS

Complex II is for FADH₂
Which donates electrons, which then get passed to Q
Which once again passes them to Complex III
Which pumps protons using electron energy

From Complex III the electrons proceed
To another mobile carrier, Cytochrome C
Which donates the electrons to Complex IV
Another proton pump, could you ask for more?

After Complex IV electrons flow,
To oxygen which is ever so
Electronegative it pulls electrons down the chain,
Keeping them moving like the cars of a train.

And as O₂ does this electron grabbing trick,
It also grabs protons from the matrix.
They all combine to form H₂O
Electron transport chain, watch it go!

CHORUS

Now all these protons in the intermembrane space
Are trapped they can't get out of that place
'Cause protons are charged and could never get through
A phospholipid bilayer, they can't diffuse

But like all particles, they're dying to go
From where their concentration's high to where it's low
Stuck in the intermembrane space they're frustrated.
To diffuse to the matrix, they're highly motivated.

And this gradient's been made steeper by O_2
Which absorbs protons from the matrix stew,
So from proton pumping, and oxygen's actions.
Add another force, electrochemical attraction!

Think of all those trapped protons, each one's positive.
The matrix, in comparison is negative.
Opposites attract, so the protons are dying
To get to matrix, oh how they're trying!

There's only one channel that let's the protons pass,
And they use it like high school students busting out of
class,
It's a channel *and* an enzyme, it's ATP synthase
The closer in this game, an energy ace

ATP synthase is embedded in the inner membrane
How it works is so cool it's insane.
It's got channels for diffusing protons running right through
it.
When cells make ATP, well watch how they do it

The matrix side of ATP synthase has binding sites
For ADP and P which come in and bind.
And as ATP synthase lets protons barge through
Their kinetic energy gets put to use.

Like water through a turbine proton movement generates
rotation.
Changing synthase's binding site conformation.
Which catalyzes chemical bond formation.
ADP and P make ATP that energy sensation!

CHORUS