Membrane Biochemistry

Lectures by

John F. Allen

School of Biological and Chemical Sciences, Queen Mary, University of London

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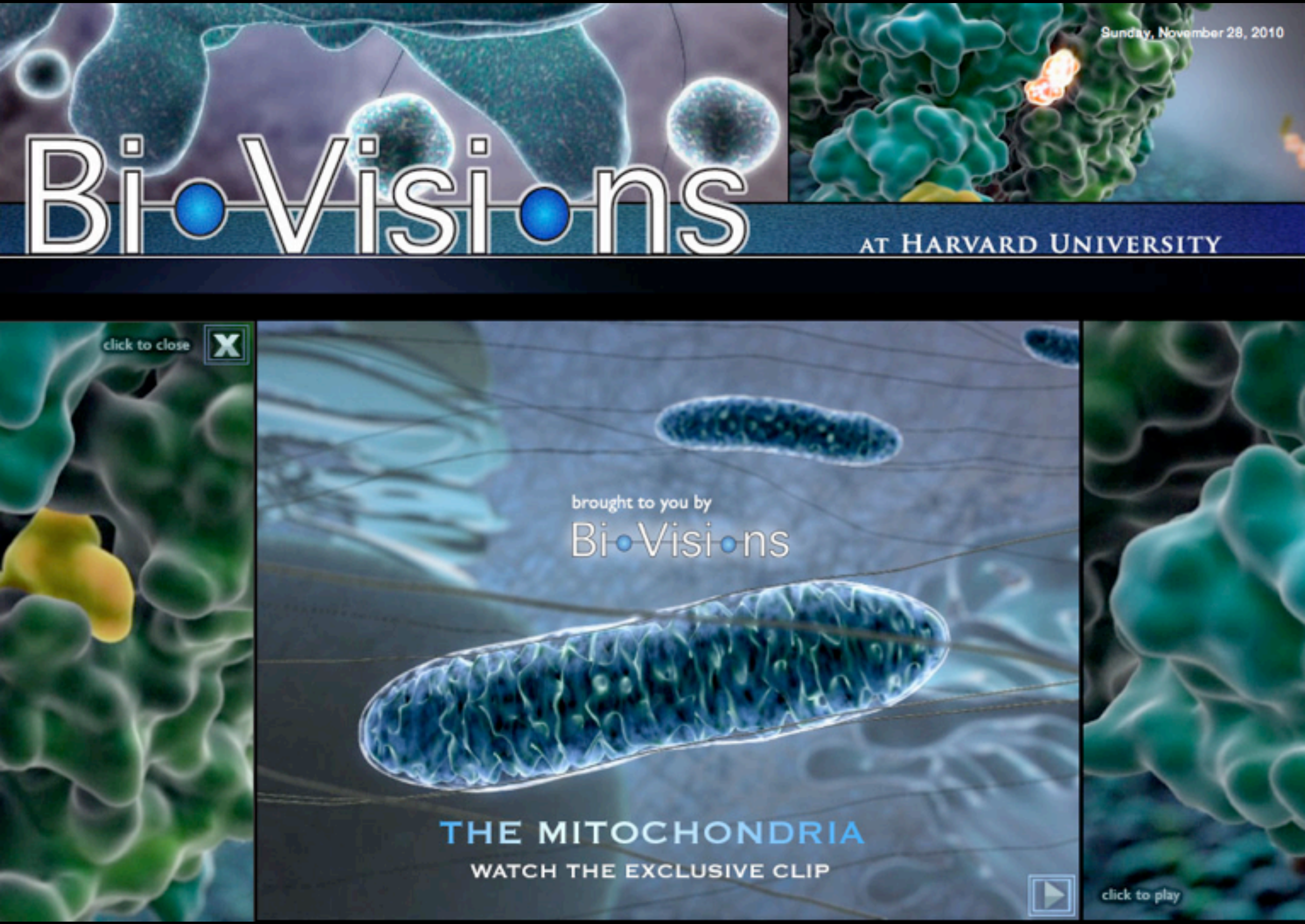
University of London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Lectures in Membrane Biochemistry by John F. Allen

http://jfallen.org/lectures/membrane_biochemistry/index.html

Further reading

- Chemiosmotic coupling: The cost of living. By Peter Rich. (.pdf file, 80 kb)
- Power for Life. Review of Nick Lane's book "Power Sex Suicide...." (.pdf file, 416 kb)
- N,K-ATPase. Page of Mark Hilge at Protein Biophysics, Nijmegen
- ATP Synthase. Group Pages of John Walker at the MRC Mitochondrial Biology Unit, Cambridge

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Animations

- The pump cycle of Na,K-ATPase. By Mark Hilge at Protein Biophysics, Nijmegen
- Animation. From Light to ATP. By O. Fritsche and W. Junge, University of Osnabruck. (.avi file, 17.7 mb)
- Molecular animations of ATP synthase. From the research group of John Walker at the MRC Mitochondrial Biology Unit, Cambridge
- Animation. Powering the Cell: Mitochondria. From BioVisions at Harvard University

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Relevant Nobel prizes

- 1906 Nobel Prize in Physiology or Medicine to Camillo Golgi and Santiago Ramón y Cajal
- 1974 Nobel Prize in Physiology or Medicine to Albert Claude, Christian de Duve and George E. Palade
- 1978 Nobel Prize in Chemistry to Peter Mitchell
- 1988 Nobel Prize in Chemistry to Johann Deisenhofer, Robert Huber and Hartmut Michel
- 1997 Nobel Prize in Chemistry to Paul D. Boyer, John E. Walker and Jens C. Skou
- 1999 Nobel Prize in Physiology or Medicine to Günter Blobel

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Lectures in Membrane Biochemistry

- The endomembrane system - endocytosis and exocytosis (Acrobat, .pdf file)
- The endomembrane system - vesicular transport and protein trafficking (Acrobat, .pdf file)
- Transport across membranes 1 - Proteins (Acrobat, .pdf file)
- Transport across membranes 2 - Small molecules and ions (Acrobat, .pdf file)
- Mitochondria and chloroplasts - analysis of compartments (Acrobat, .pdf file)
- Bioenergetics (Acrobat, .pdf file)
- The respiratory chain and oxidative phosphorylation (Acrobat, .pdf file)
- Oxidative phosphorylation, respiratory control and the chemiosmotic hypothesis (Acrobat, .pdf file)
- ATP Synthase - Coupling ATPase (Acrobat, .pdf file)

Course web pages

Membrane Biochemistry web pages

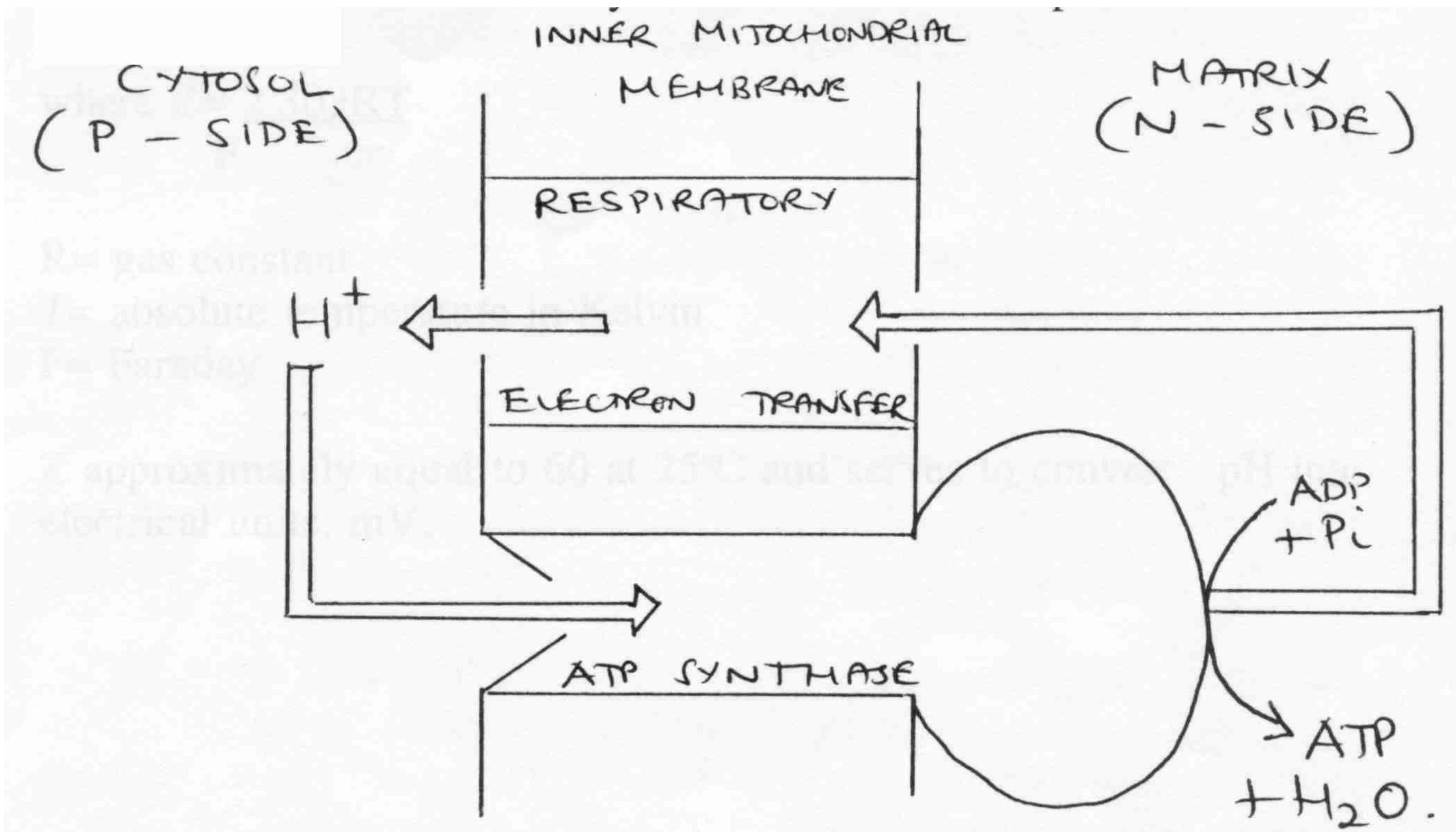
General reference

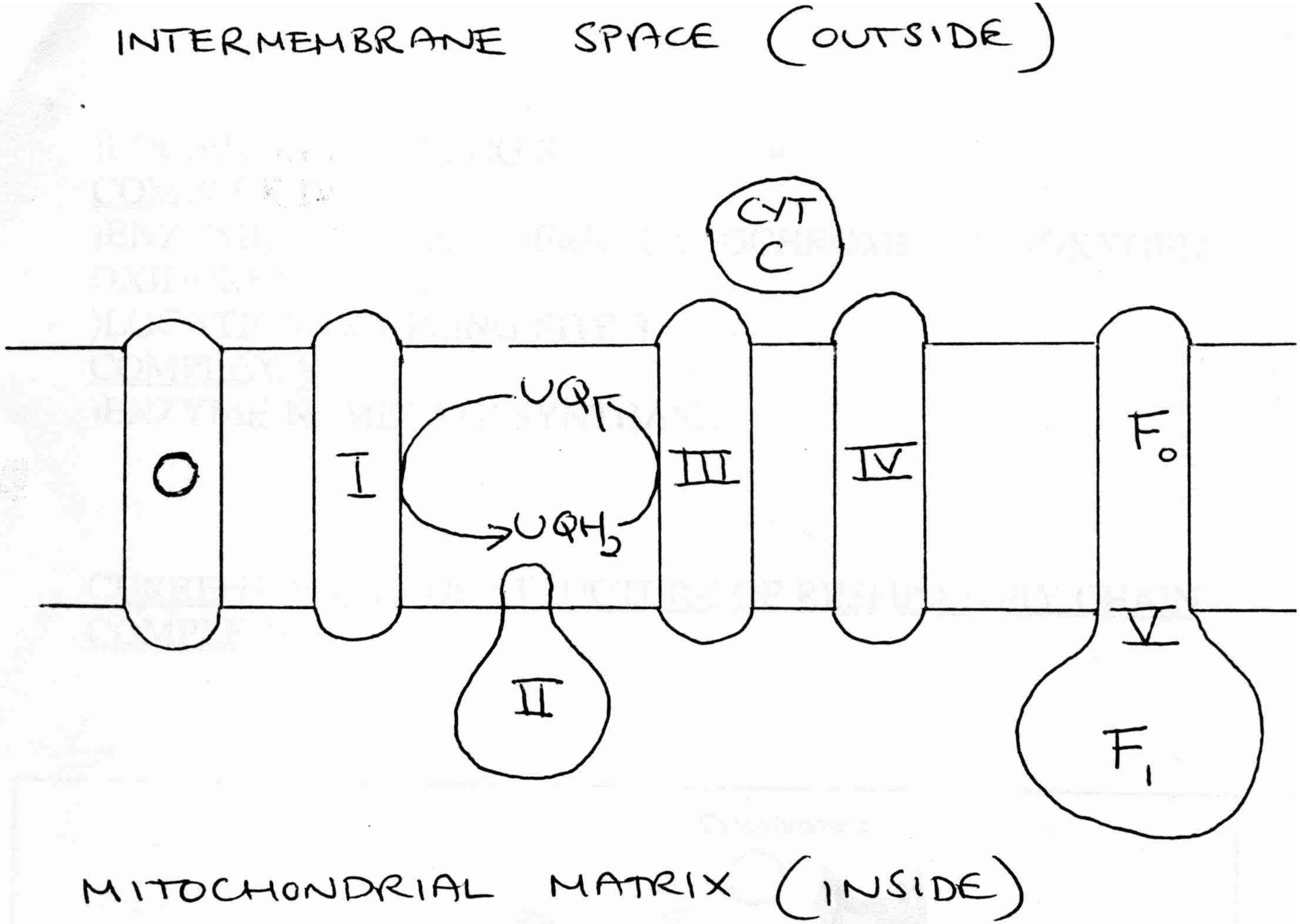
Cell and Molecular Biology: Concepts and Experiments
Gerald Karp. Fifth Edition 2008. John Wiley & Sons Inc.

ATP Synthase – Coupling ATPase

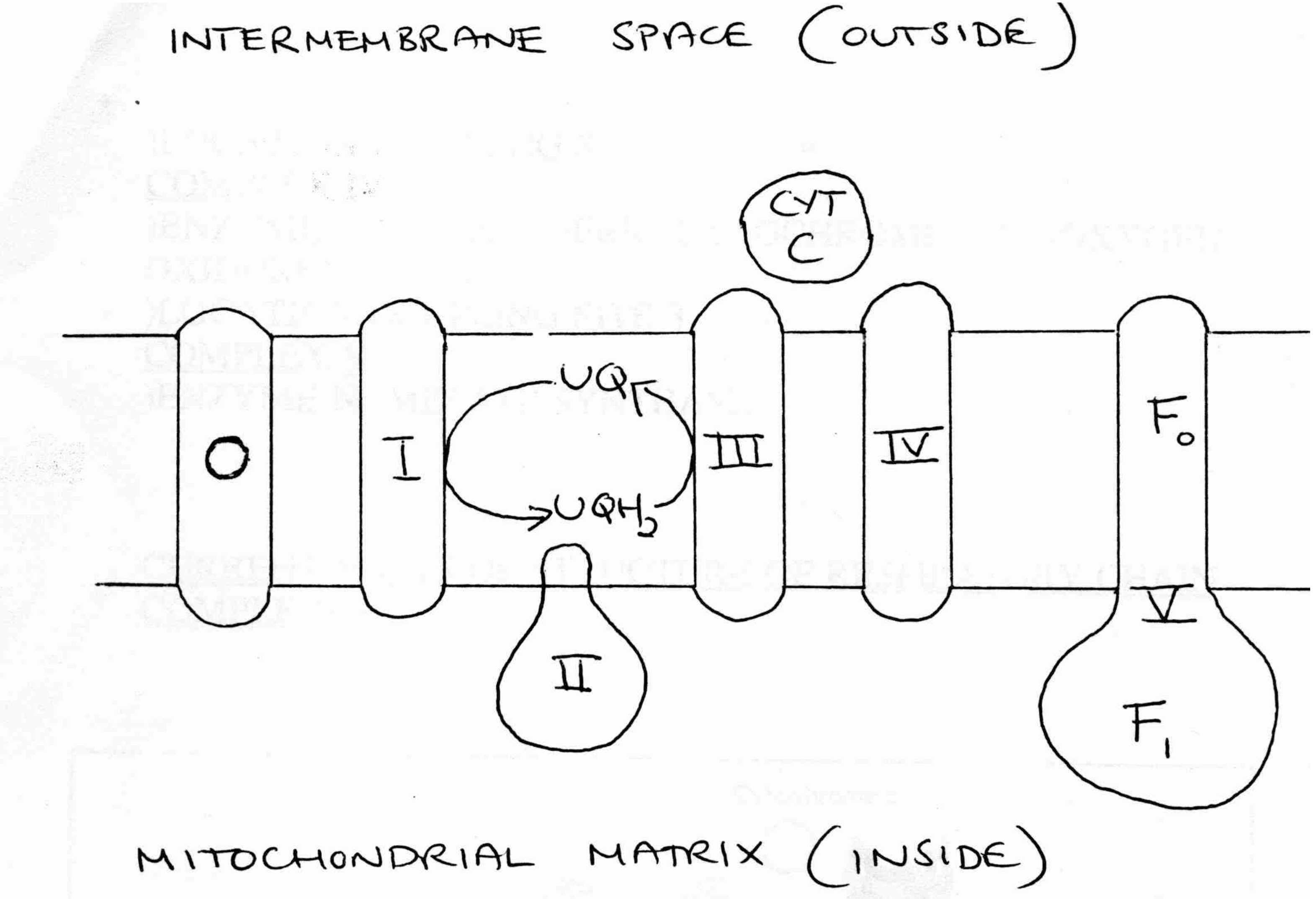
<u>Transmembrane Proton gradient</u>

Energy transduction occurs by means of a proton circuit through the insulating, coupling membrane and between the two bulk aqueous phases (the matrix and the intermembrane space/cytosol in mitochondria).




INTERMEMBRANE SPACE (OUTSIDE)
CYT C
O
I
UQ
UQH2
II
III
IV
F0
V
F1
MITOCHONDRIAL MATRIX (INSIDE)

COMPLEX V


INTERMEMBRANE SPACE (OUTSIDE)
CYT C
UQ
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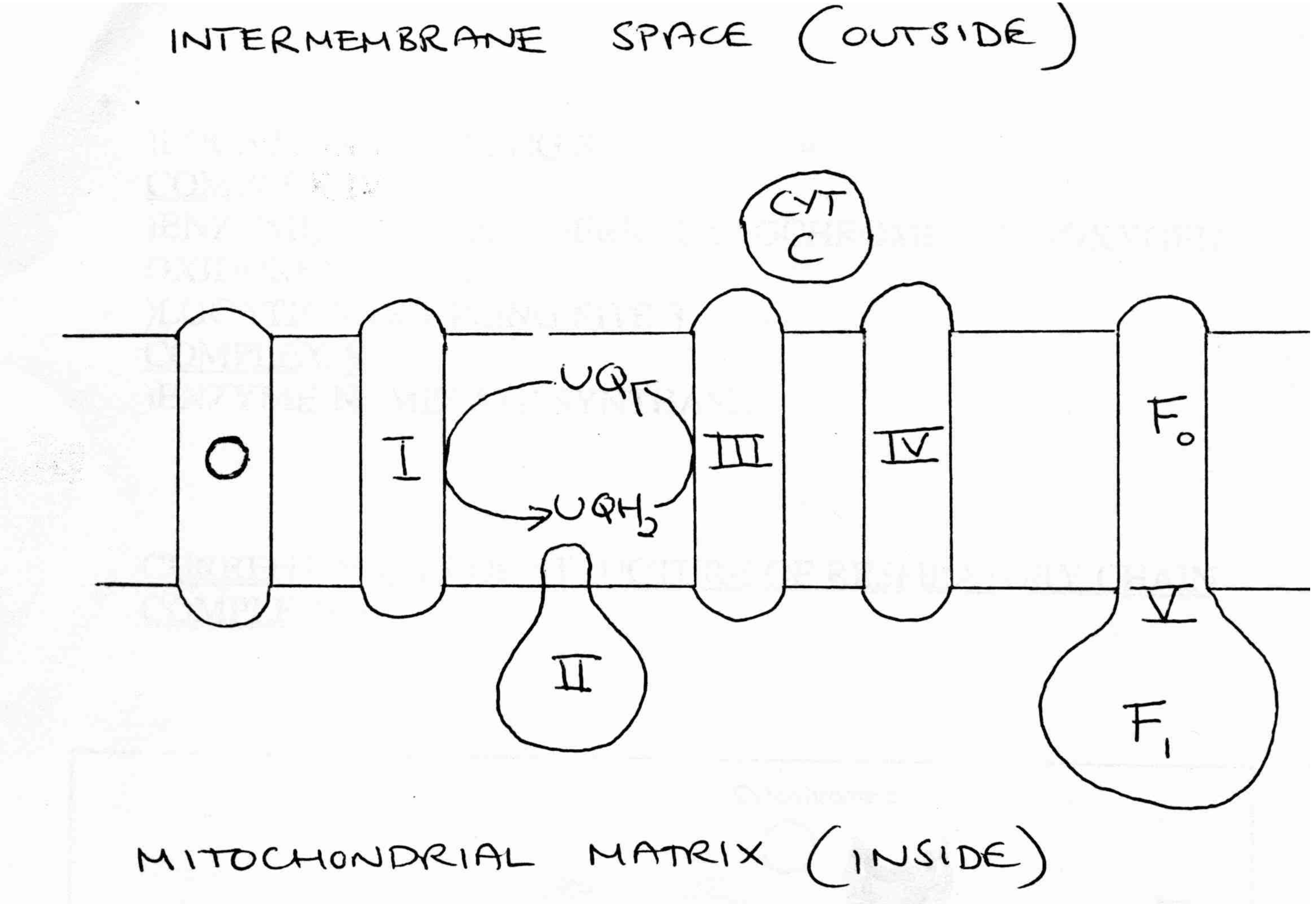
MITOCHONDRIAL MATRIX (INSIDE)

COMPLEX V

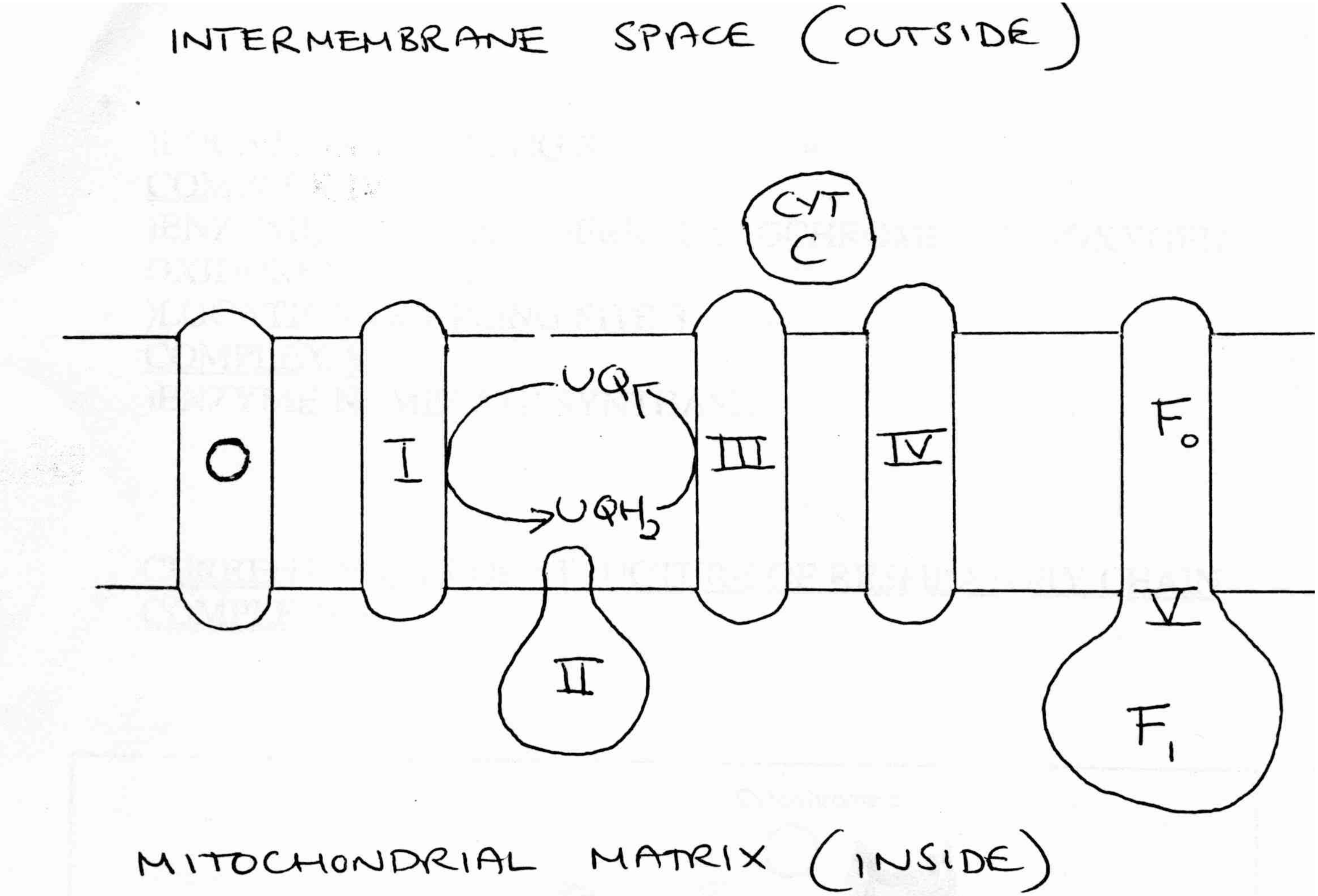
ENZYME NAME: COUPLING ATPase; ATP SYNTHASE



COMPLEX V

ENZYME NAME: COUPLING ATPase; ATP SYNTHASE

F-ATPase

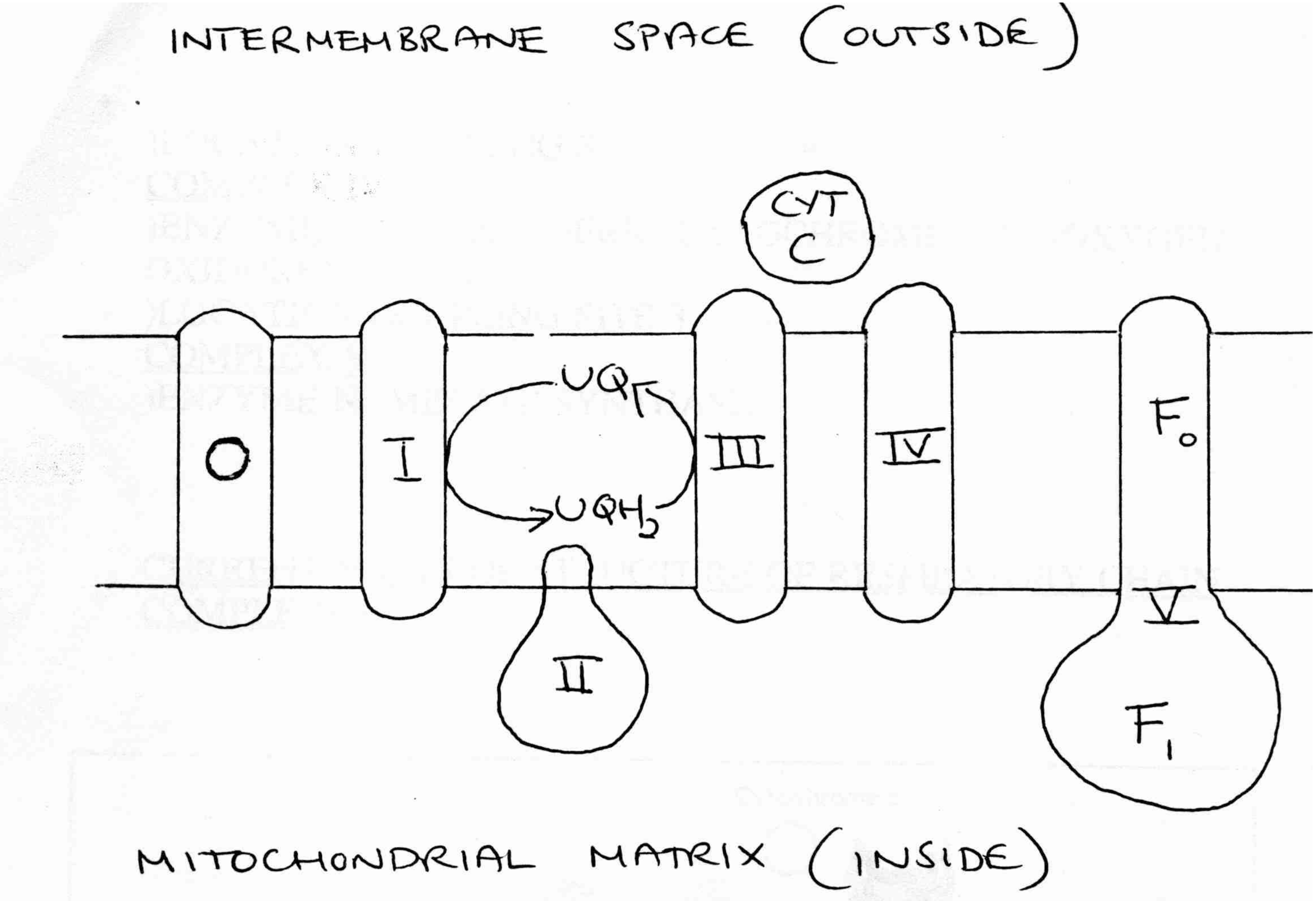


COMPLEX V

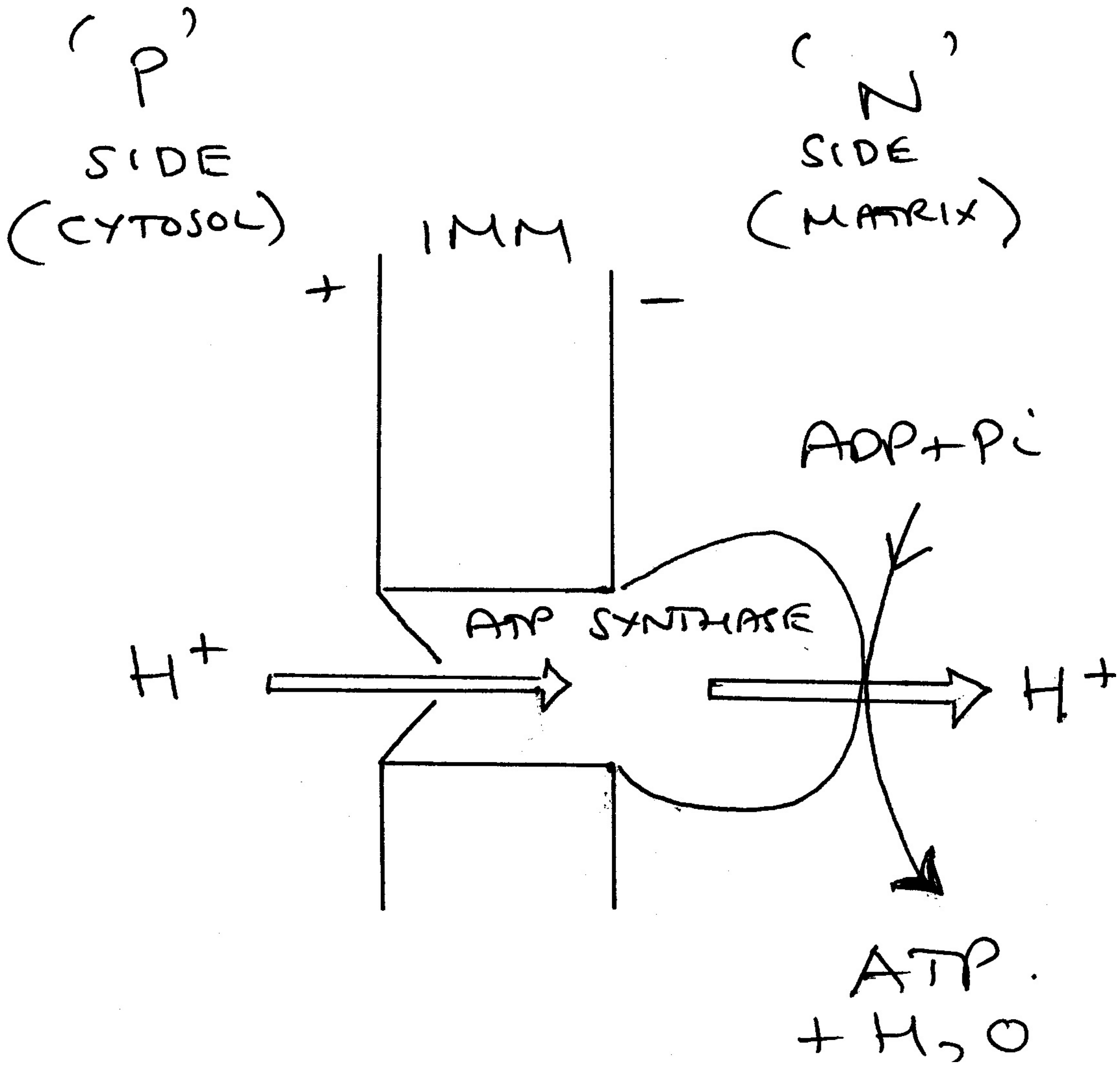
ENZYME NAME: COUPLING ATPase; ATP SYNTHASE

F-ATPase

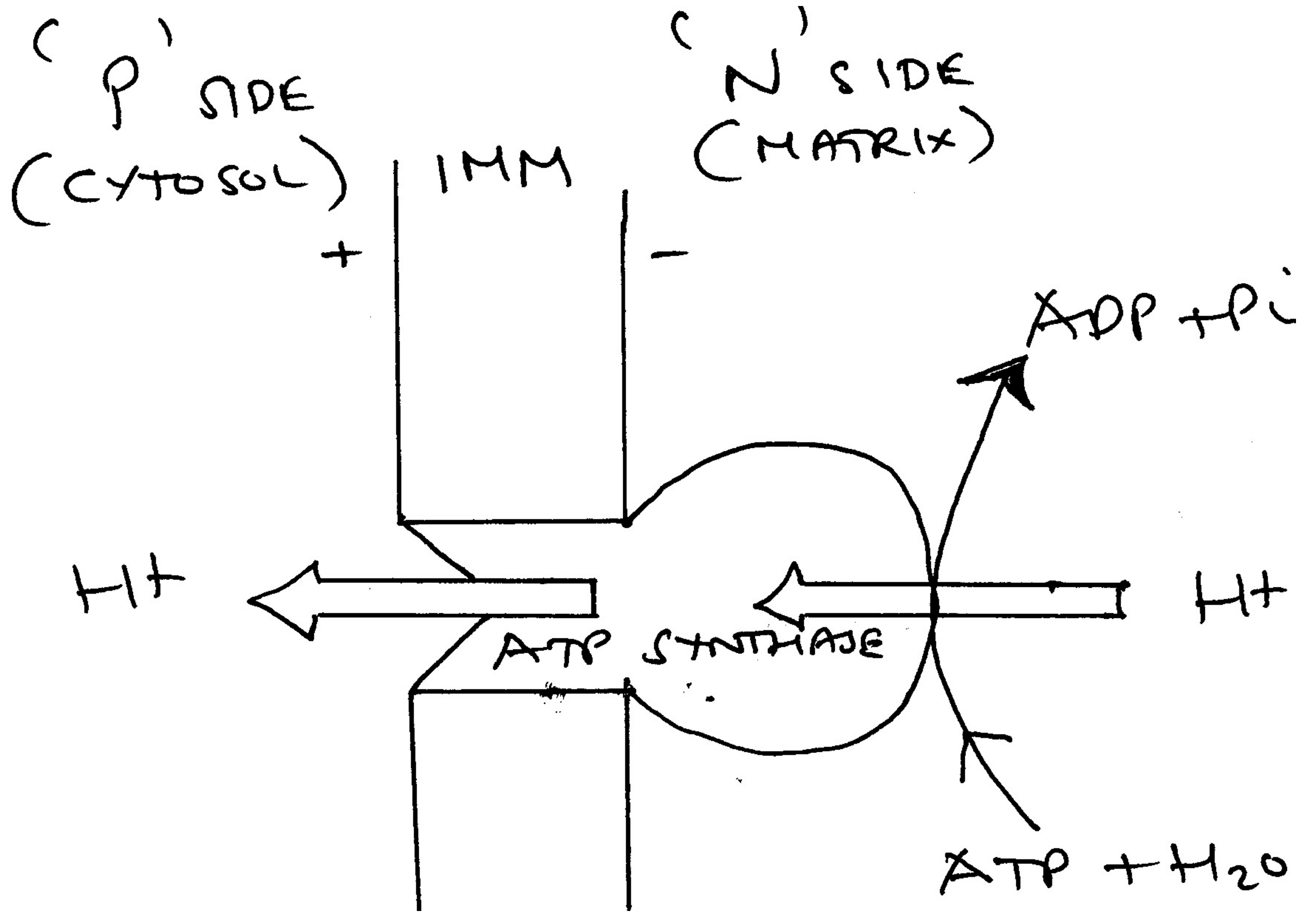
F_1-F_o ATPase



ATP synthase can transport protons across the membrane in one direction down the concentration (Δ pH) and charge (Δψ) gradient , using the energy for ATP synthesis.



Alternatively the ATP synthase can use the energy from ATP hydrolysis to pump protons in the opposite direction (active transport against the concentration and charge gradient).



Evidence for ΔpH–driven ATP synthesis

1. The 'acid-bath experiment'. ΔpH driving ATP synthesis was demonstrated in 1966 by Jagendorf and Uribe, using thylakoid membranes of chloroplasts.

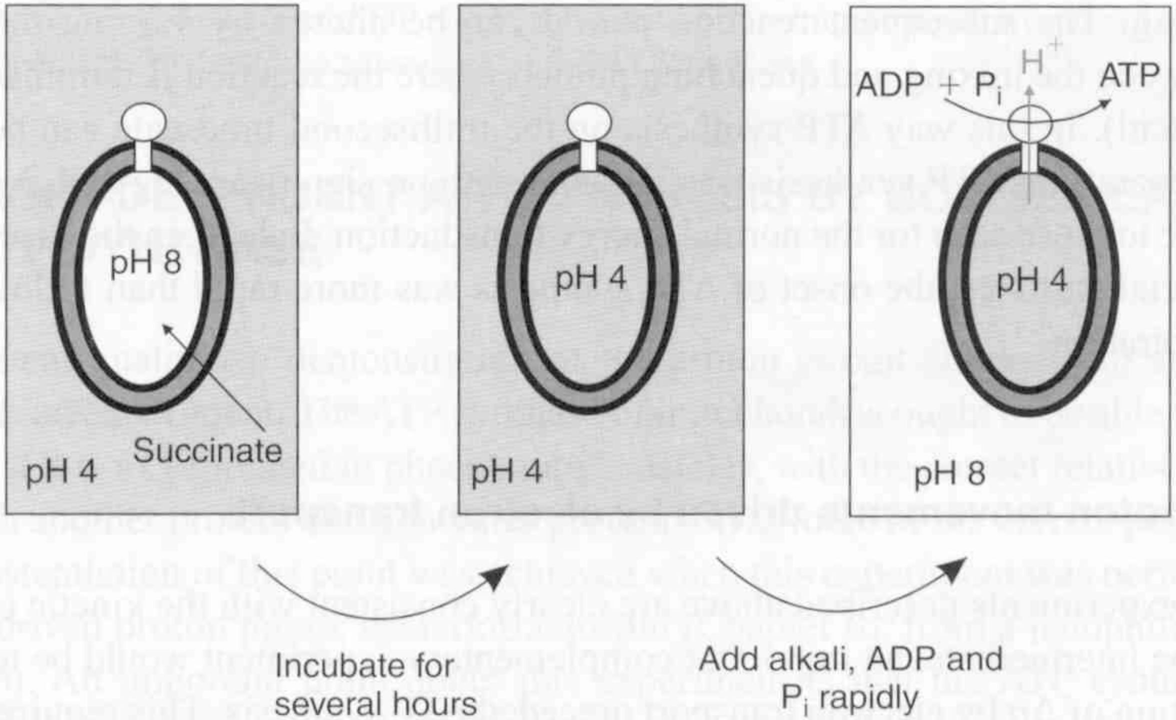


Figure 4.15 The 'acid bath' experiment: a ΔpH can generate ATP. Thylakoid membranes were incubated in the dark at pH 4 in the presence of electron transport inhibitors in a medium containing succinate, which slowly permeated into the thylakoid space liberating protons and lowering the internal pH to about 4. The external pH was then suddenly raised to 8, creating a ΔpH of 4 units across the membrane. Traditionally H^+ efflux through the ATP synthase has been regarded as charge compensated by Cl^- efflux and/or Mg^{2+} influx. A $\Delta\psi$ may also be induced, see text. ADP and P_i were simultaneously added and proton efflux through the ATP synthase led to the synthesis of about 100 mol of ATP per mol of synthase. Protonophores such as FCCP inhibited the ATP production.

Coupling ATPase

Coupling ATPase

$$ATP + H_2O \rightleftharpoons ADP + P_i$$

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Also known as “ATP Synthase”

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$$ATP + H_2O \rightleftharpoons ADP + P_i$$

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One of the class of F-ATPases (c.f. V-ATPases; P-ATPases)

Coupling ATPase

$$ATP + H_2O \rightleftharpoons ADP + P_i$$

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One of the class of F-ATPases (c.f. V-ATPases; P-ATPases)

- F_1

Coupling ATPase

$$ATP + H_2O \rightleftharpoons ADP + P_i$$

Also known as “ATP Synthase”

One of the class of F-ATPases (c.f. V-ATPases; P-ATPases)

- F_1
- F_o

Coupling ATPase

$$ATP + H_2O \rightleftharpoons ADP + P_i$$

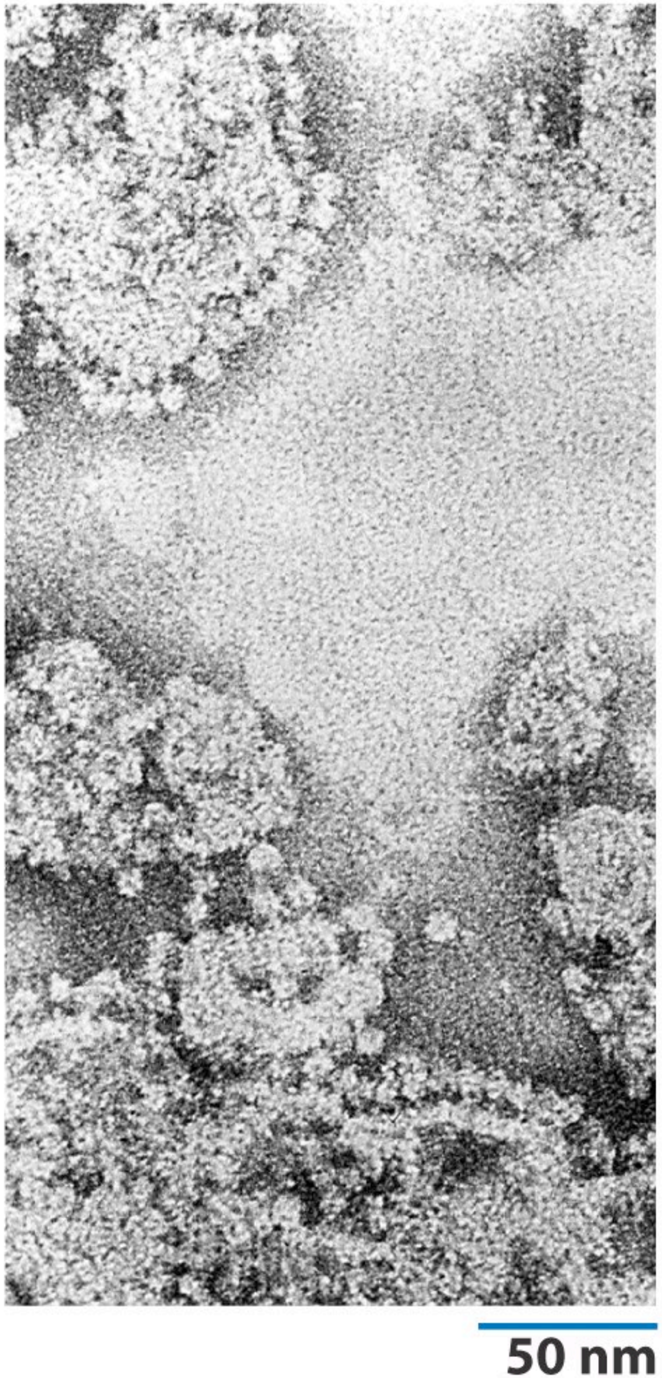
Also known as “ATP Synthase”

Also known previously as respiratory “complex V”

One of the class of F-ATPases (c.f. V-ATPases; P-ATPases)

- F_1
- F_o

F_1



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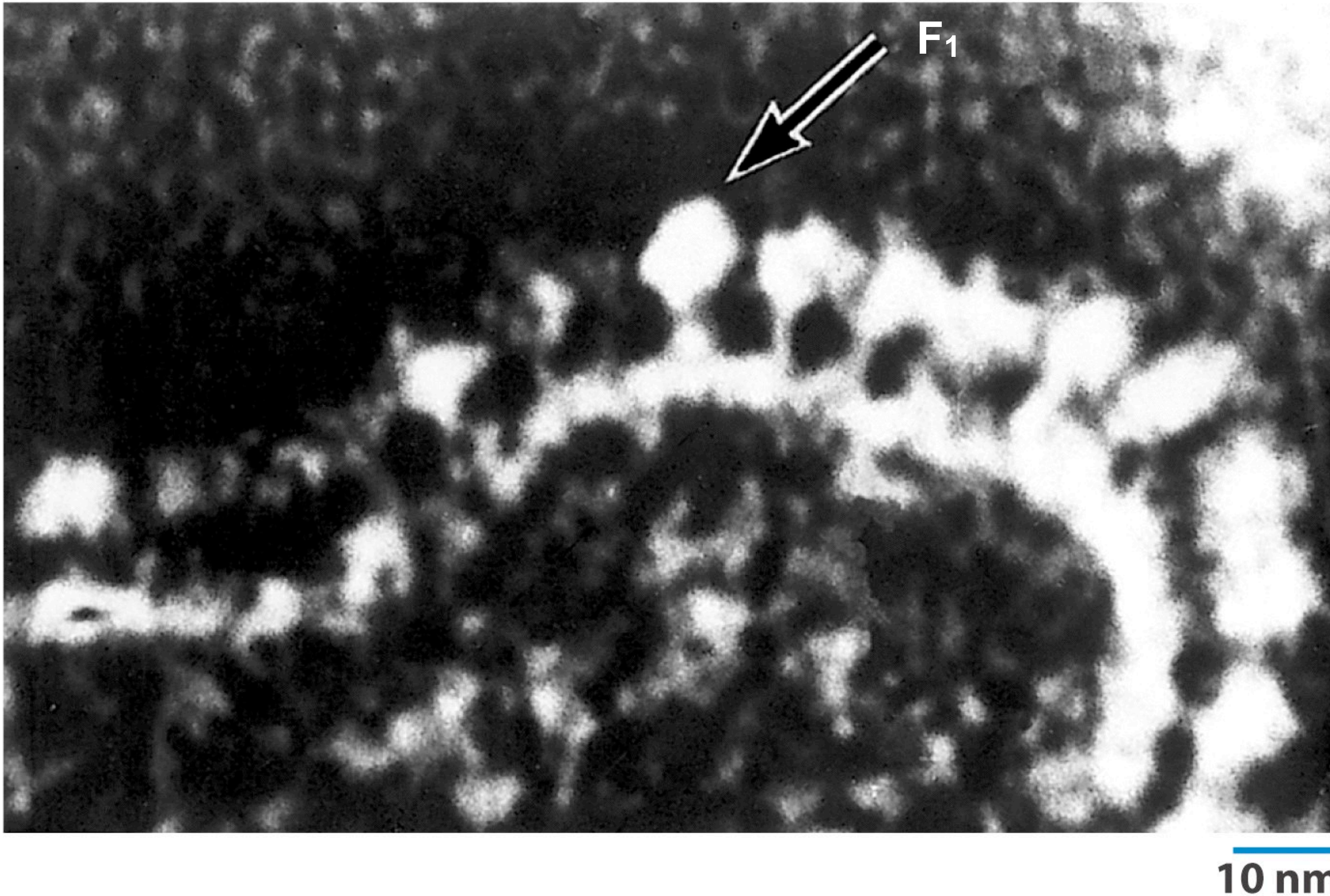

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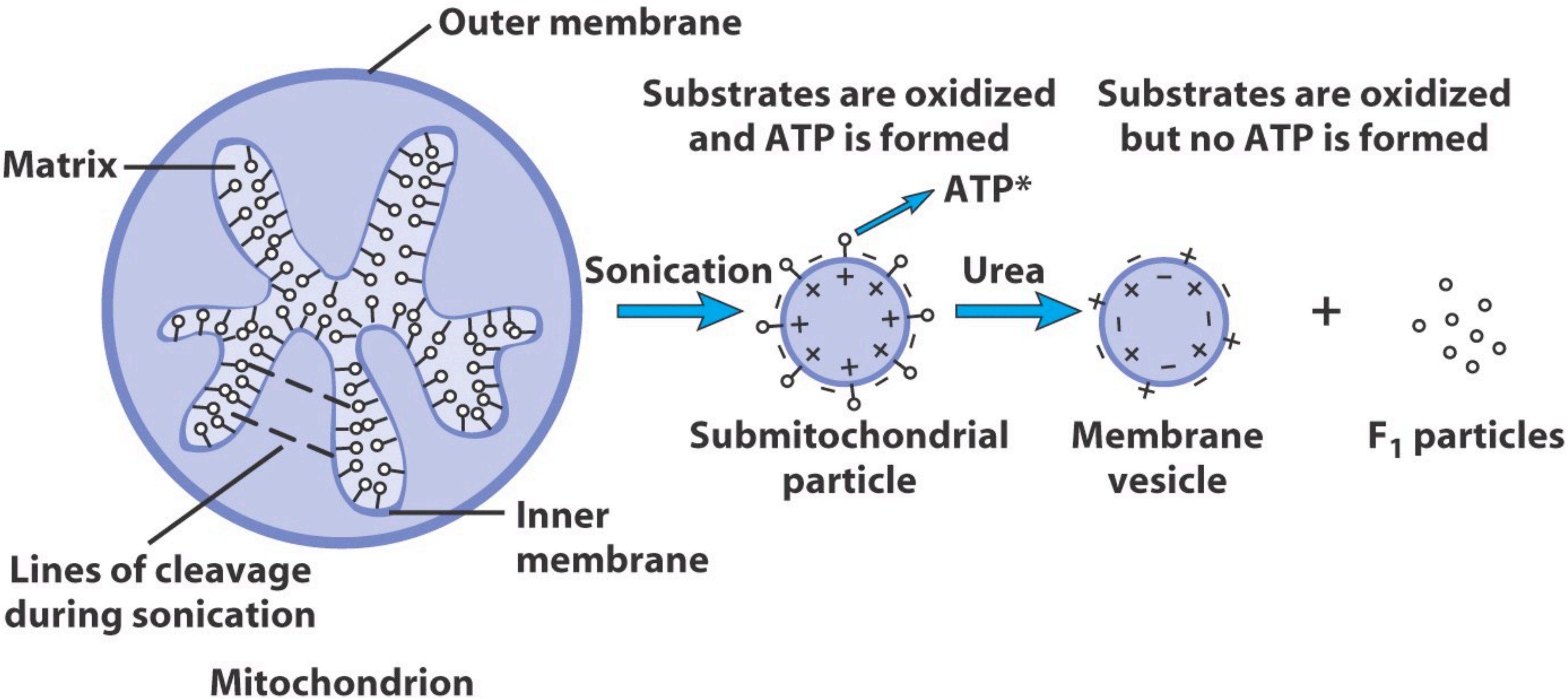


Figure 5-25b Cell and Molecular Biology, 4/e (© 2005 John Wiley & Sons)

Evidence for ΔpH–driven ATP synthesis

2. Experiment of Racker and co-workers, demonstrating light-driven ATP synthesis in lipid vesicles containing bacteriorhodopsin (a light-drive proton pump) and ATP synthase from mitochondria from beef heart

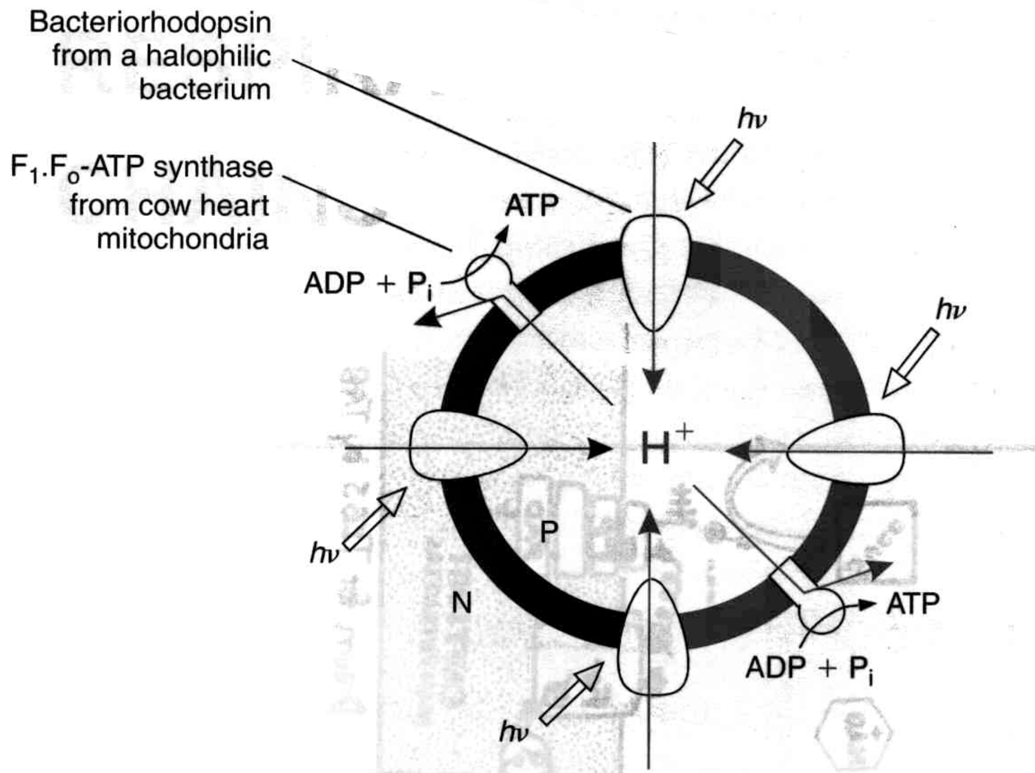
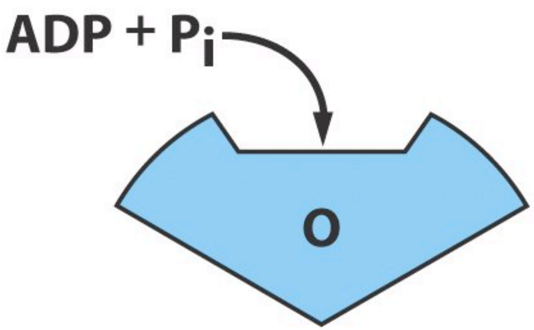


Figure 4.16 A proton circuit between a light-driven proton pump (bacteriorhodopsin) and ATP synthase from mitochondria.
The establishment of the proton circuit depends on the majority of the bacteriorhodopsin molecules adopting (for poorly understood reasons) the orientation in which they pump protons inward. Similarly, the ATP synthase had to incorporate predominantly with the topology shown. Opposite orientations of both bacteriorhodopsin and ATP synthase would in principle also have permitted an H^+ circuit, in the opposite direction, to be established. In practice, this would have meant that added ADP and P_i (both membrane impermeant) would not have been able to reach the active site of the ATP synthase.



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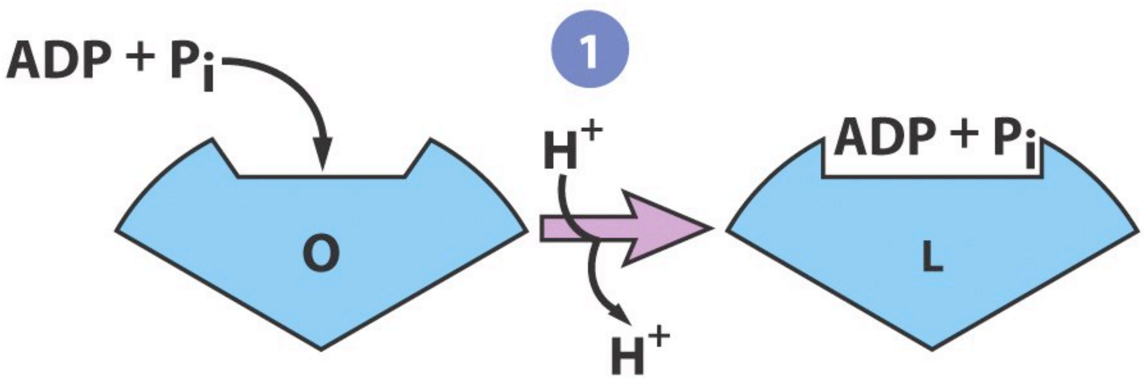

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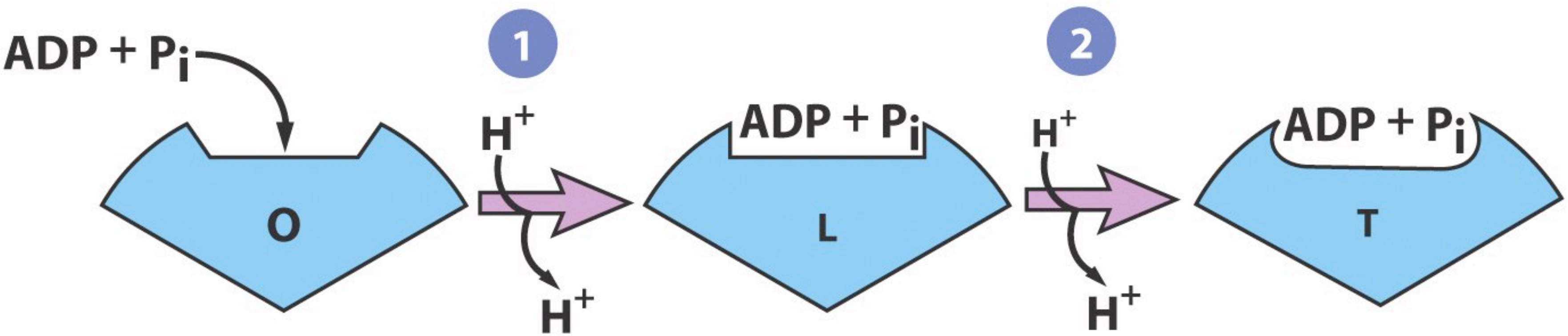

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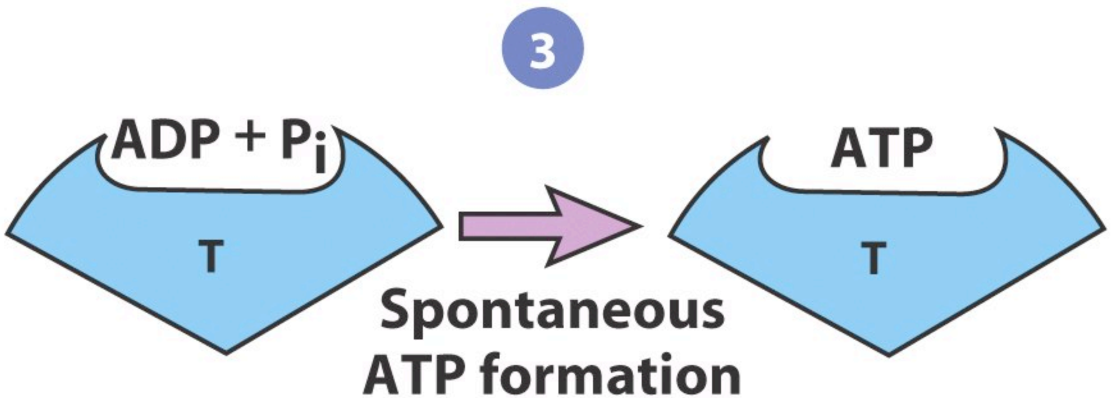

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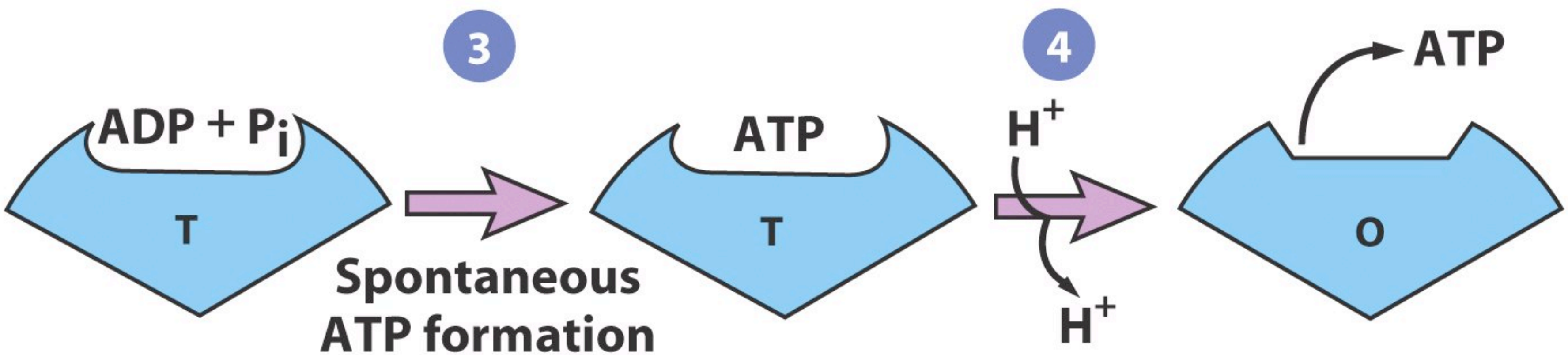

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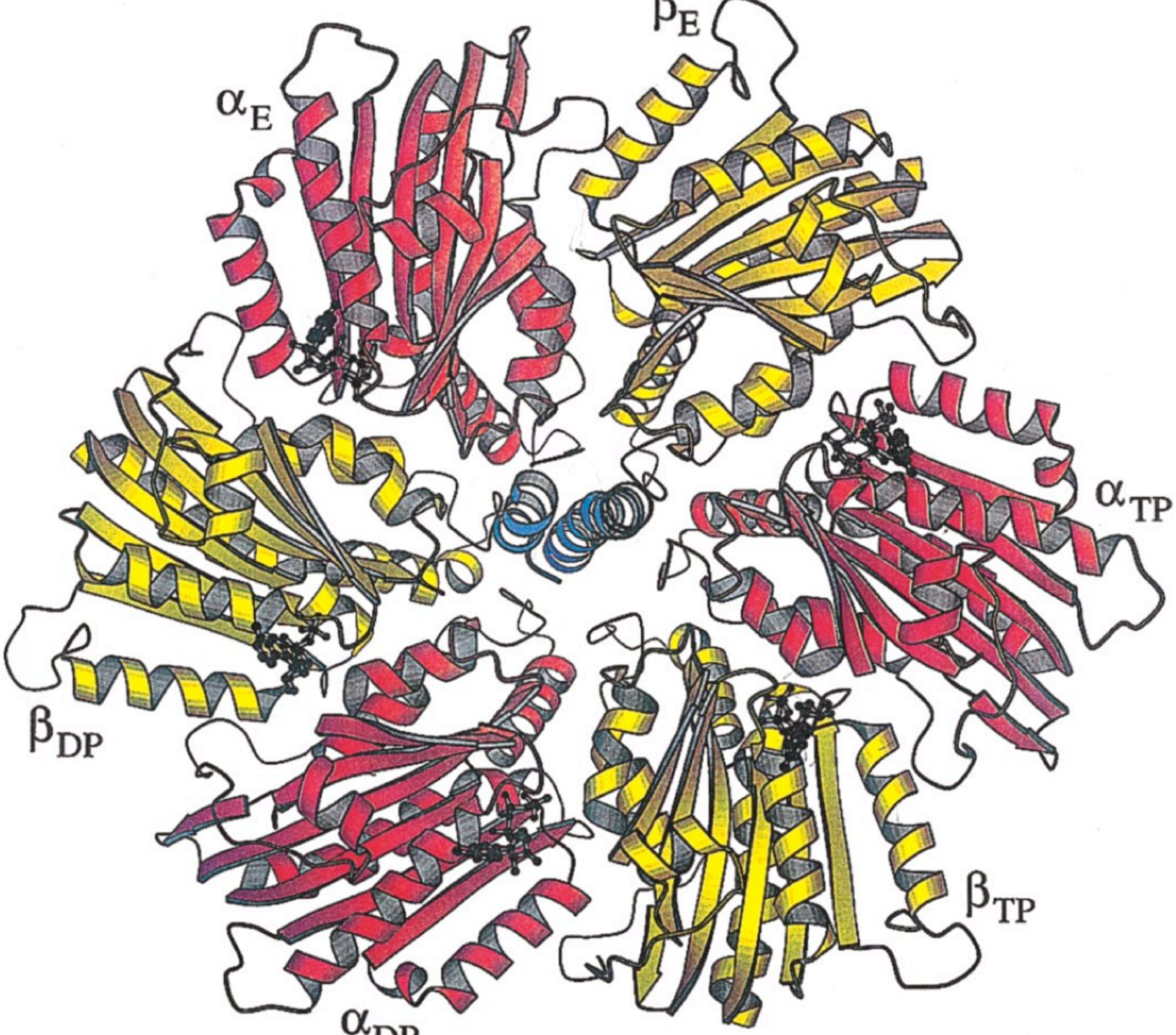

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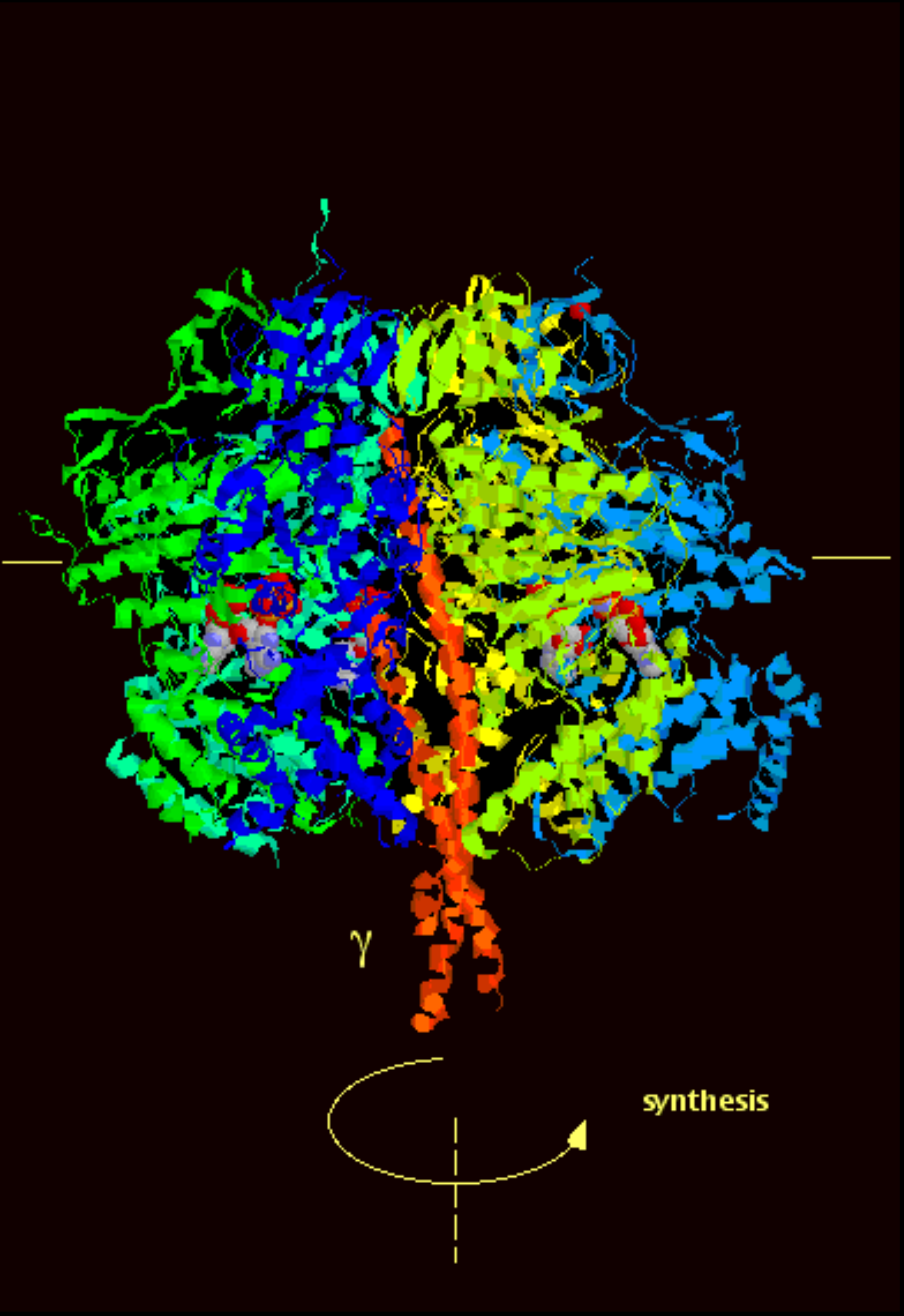


Figure from: ALLEN, J F (2002) Photosynthesis of ATP - Electrons, Proton Pumps, Rotors, and Poise. Cell 110, 273–276

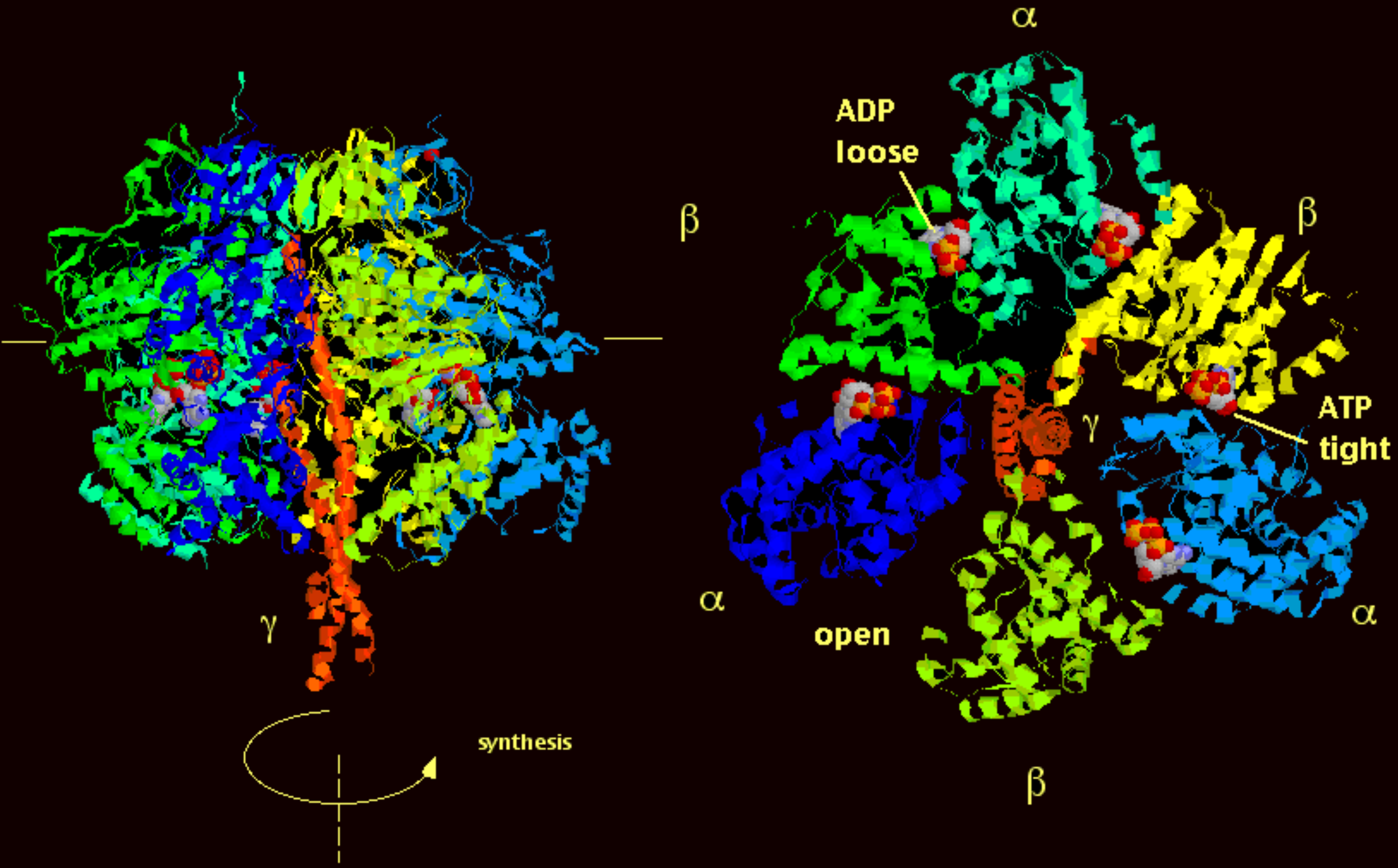
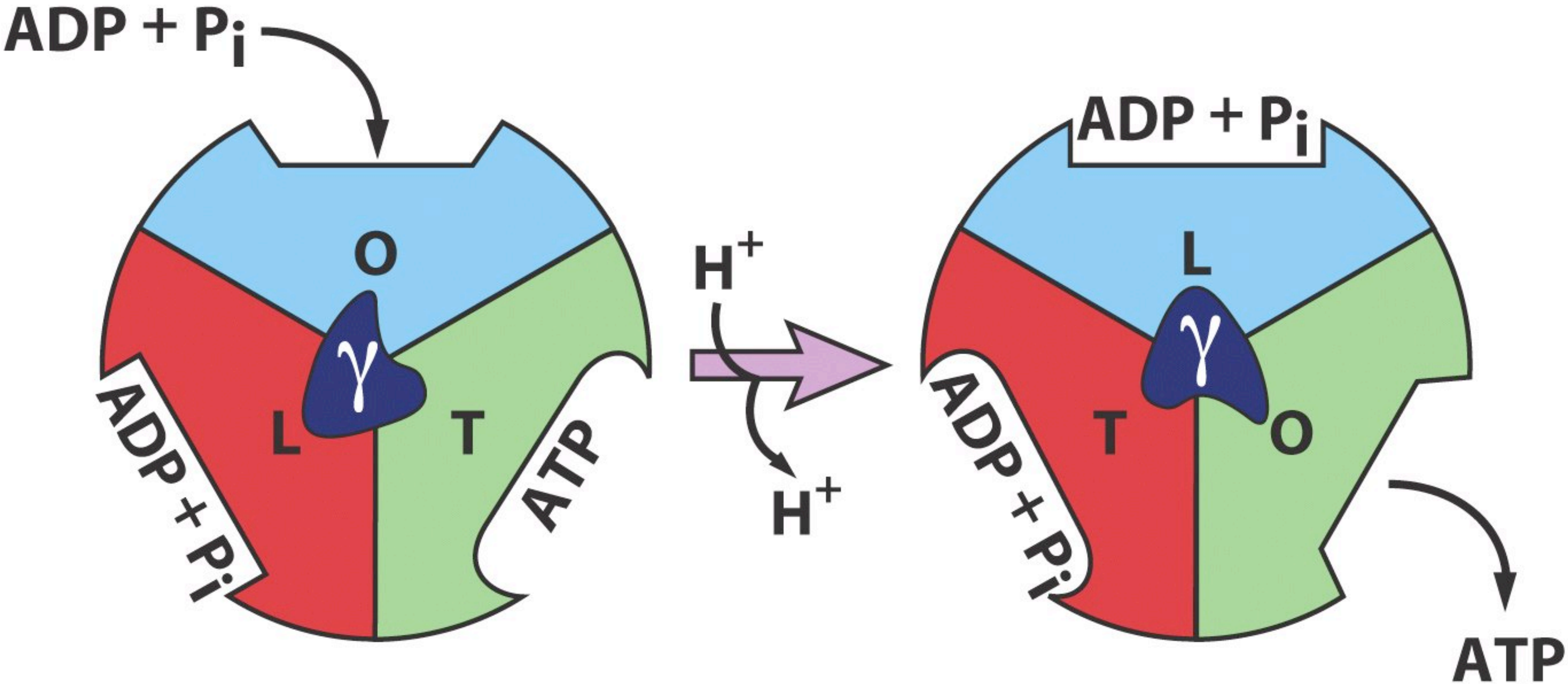


Figure from: ALLEN, J F (2002) Photosynthesis of ATP - Electrons, Proton Pumps, Rotors, and Poise. Cell 110, 273–276



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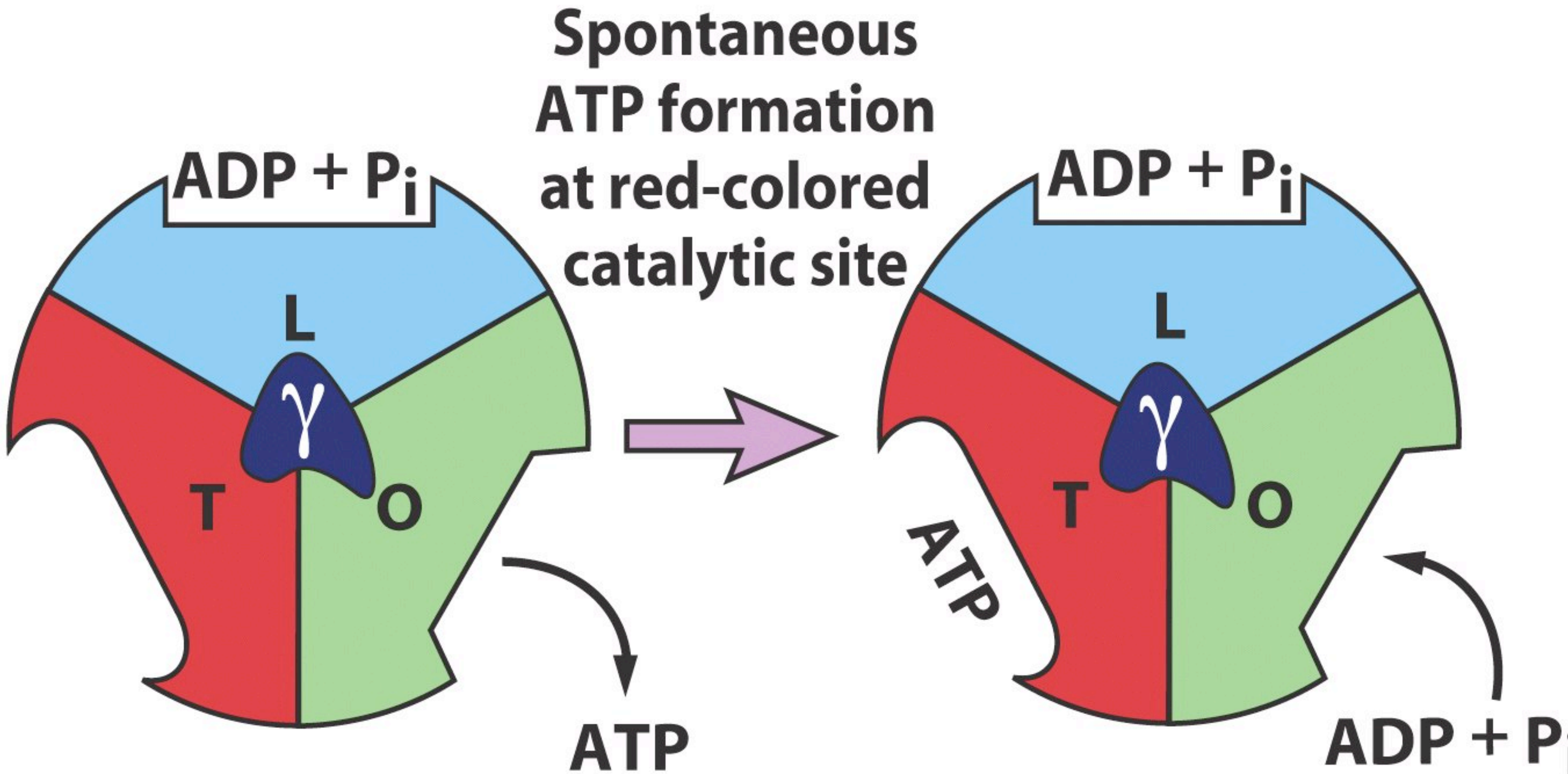

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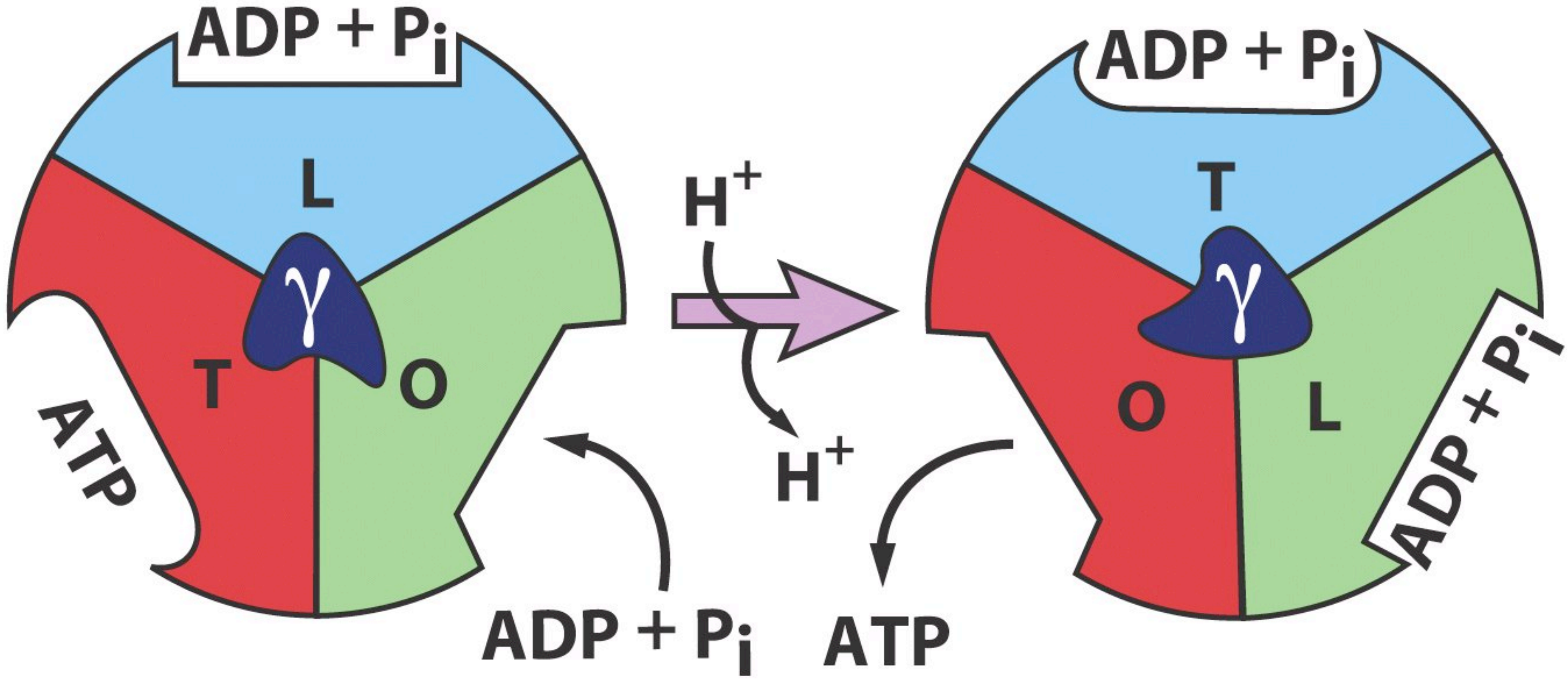

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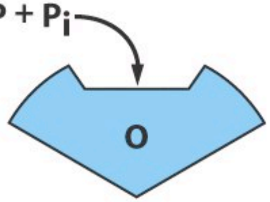

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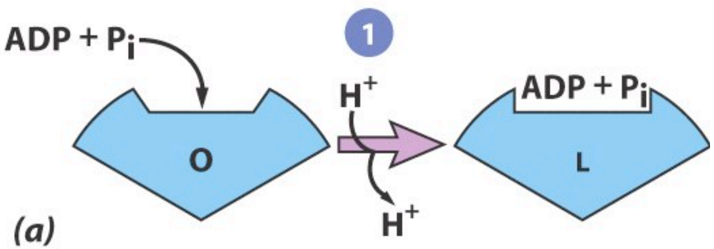

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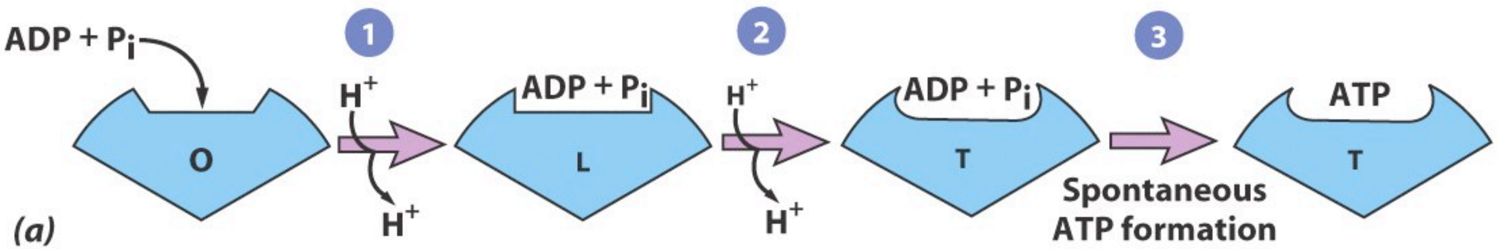

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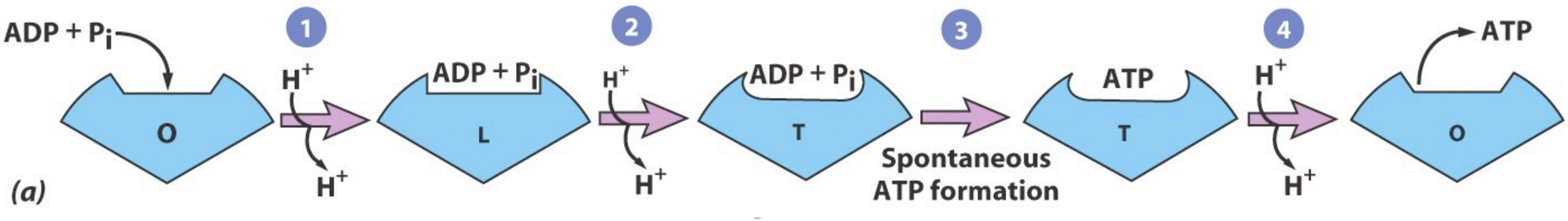

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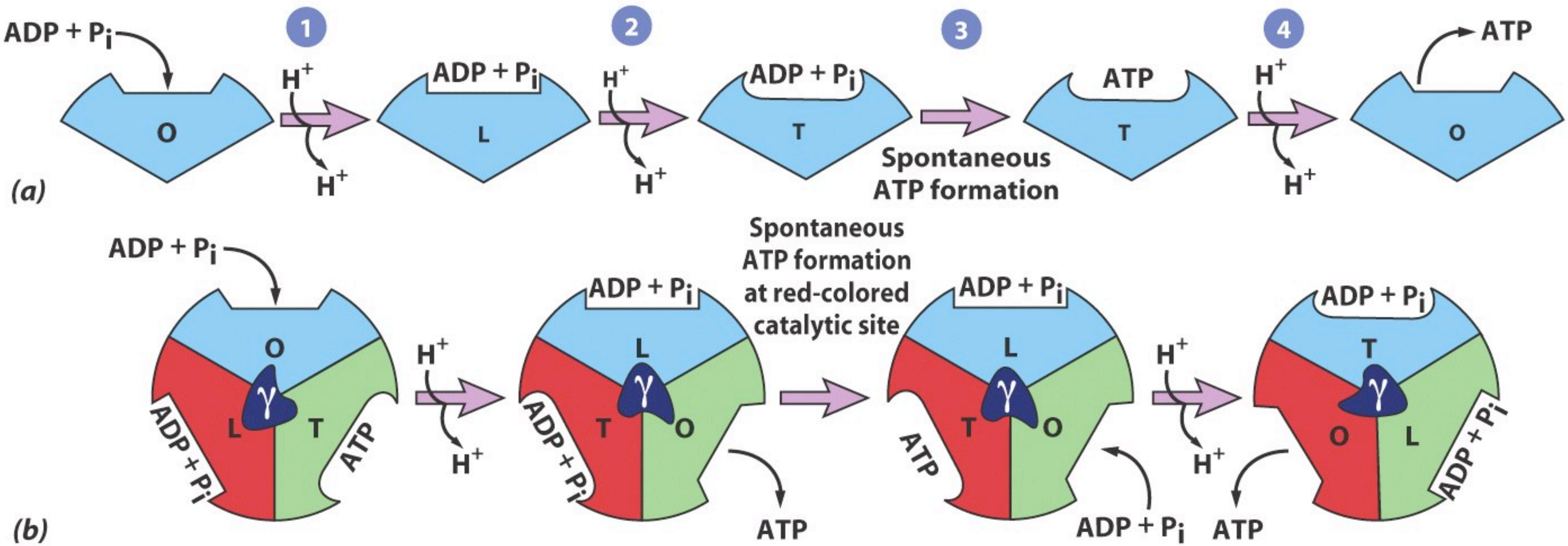

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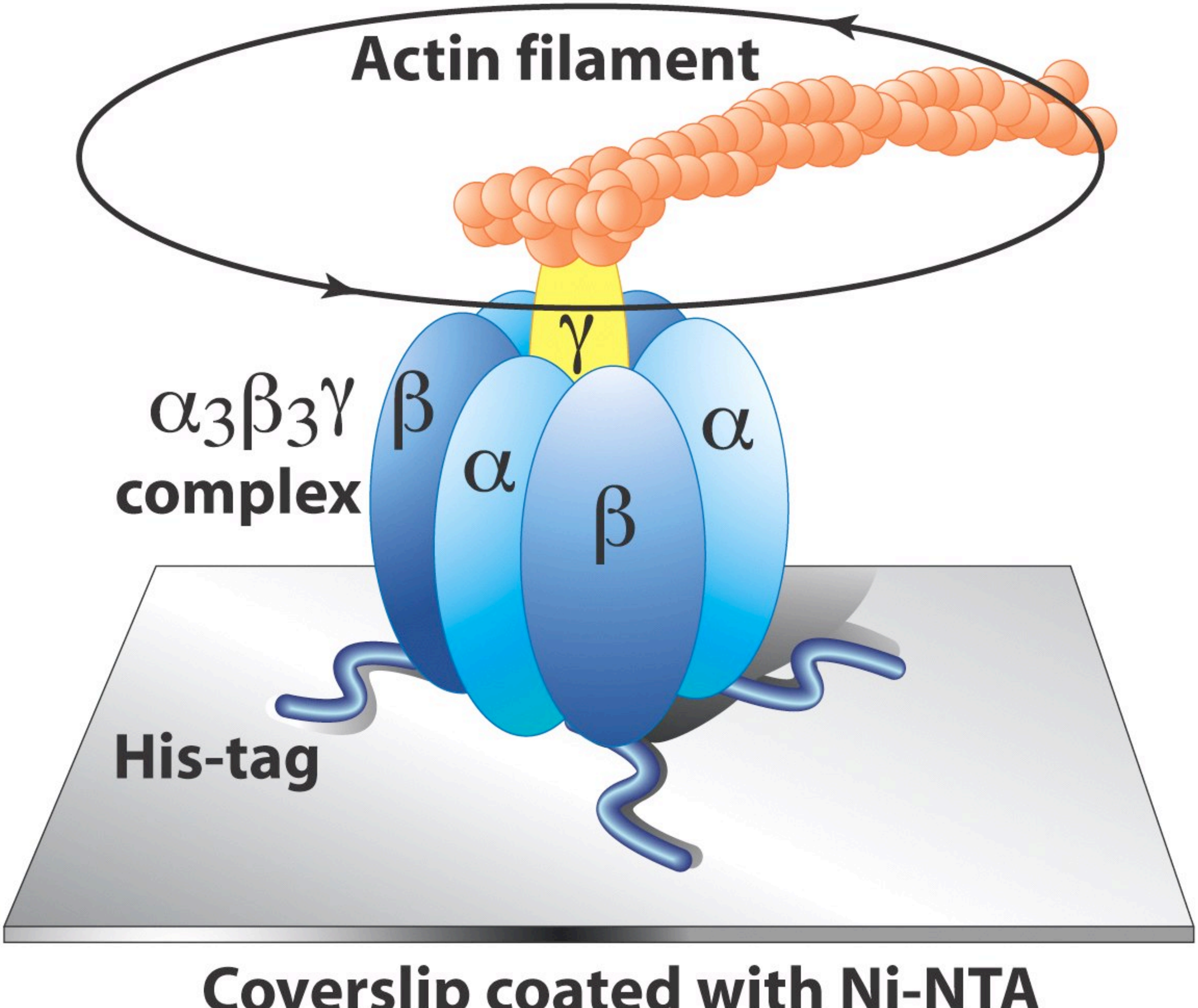

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The Nobel Prize in Chemistry 1978

"for his contribution to the understanding of biological energy transfer through the formulation of the chemiosmotic theory"

Peter D. Mitchell

United Kingdom

Glynn Research Laboratories
Bodmin, United Kingdom

b. 1920
d. 1992

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Chemistry
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Peter Mitchell
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Nobel Lecture
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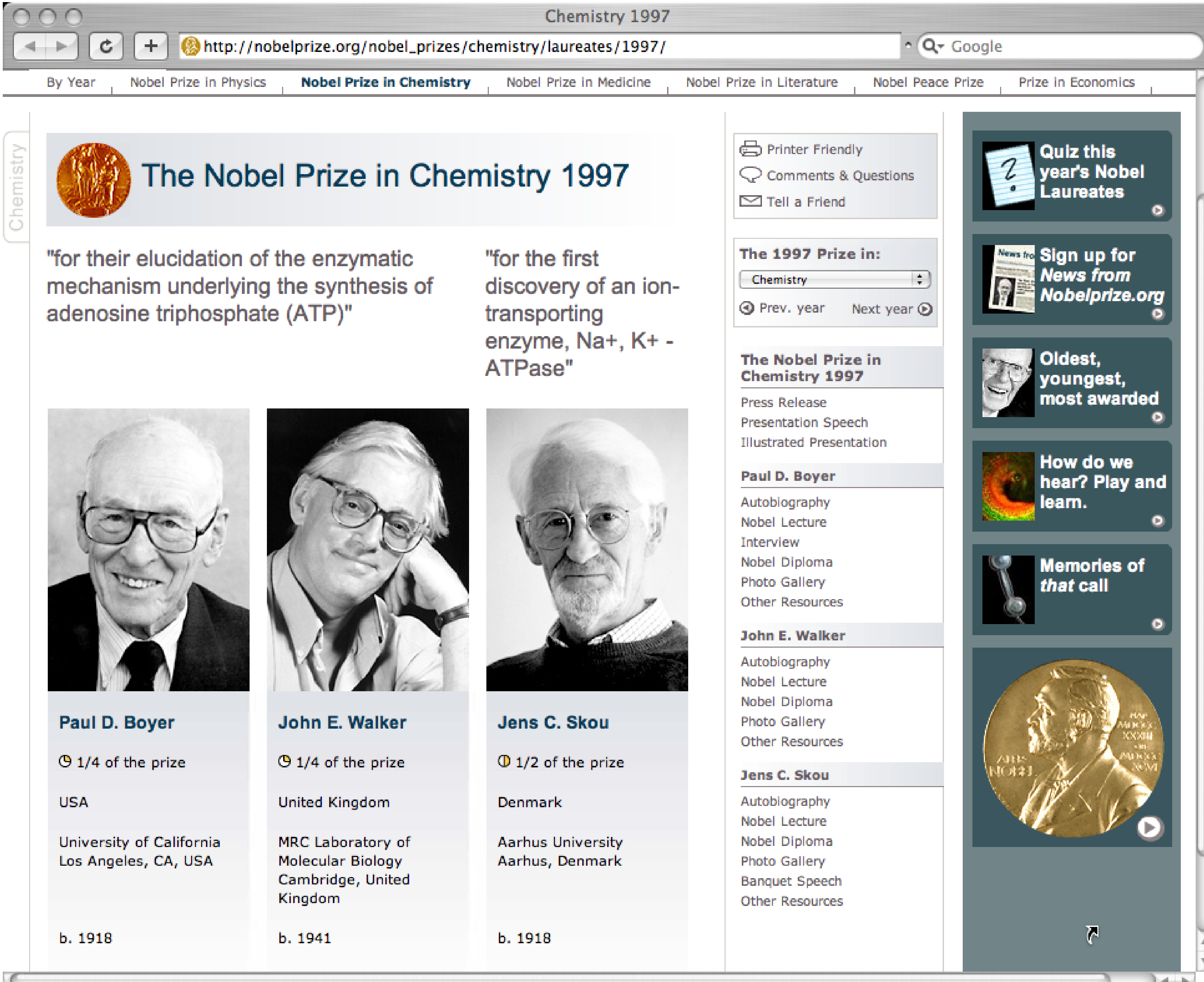
Chemistry 1997
http://nobelprize.org/nobel_prizes/chemistry/laureates/1997/
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By Year
Nobel Prize in Physics
Nobel Prize in Chemistry
Nobel Prize in Medicine
Nobel Prize in Literature
Nobel Peace Prize
Prize in Economics
Chemistry
The Nobel Prize in Chemistry 1997
"for their elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosphate (ATP)"
"for the first discovery of an ion-transporting enzyme, Na+, K+ -ATPase"
Paul D. Boyer
1/4 of the prize
USA
University of California Los Angeles, CA, USA
b. 1918
John E. Walker
1/4 of the prize
United Kingdom
MRC Laboratory of Molecular Biology Cambridge, United Kingdom
b. 1941
Jens C. Skou
1/2 of the prize
Denmark
Aarhus University Aarhus, Denmark
b. 1918
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Next year
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Illustrated Presentation
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Autobiography
Nobel Lecture
Interview
Nobel Diploma
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Other Resources
John E. Walker
Autobiography
Nobel Lecture
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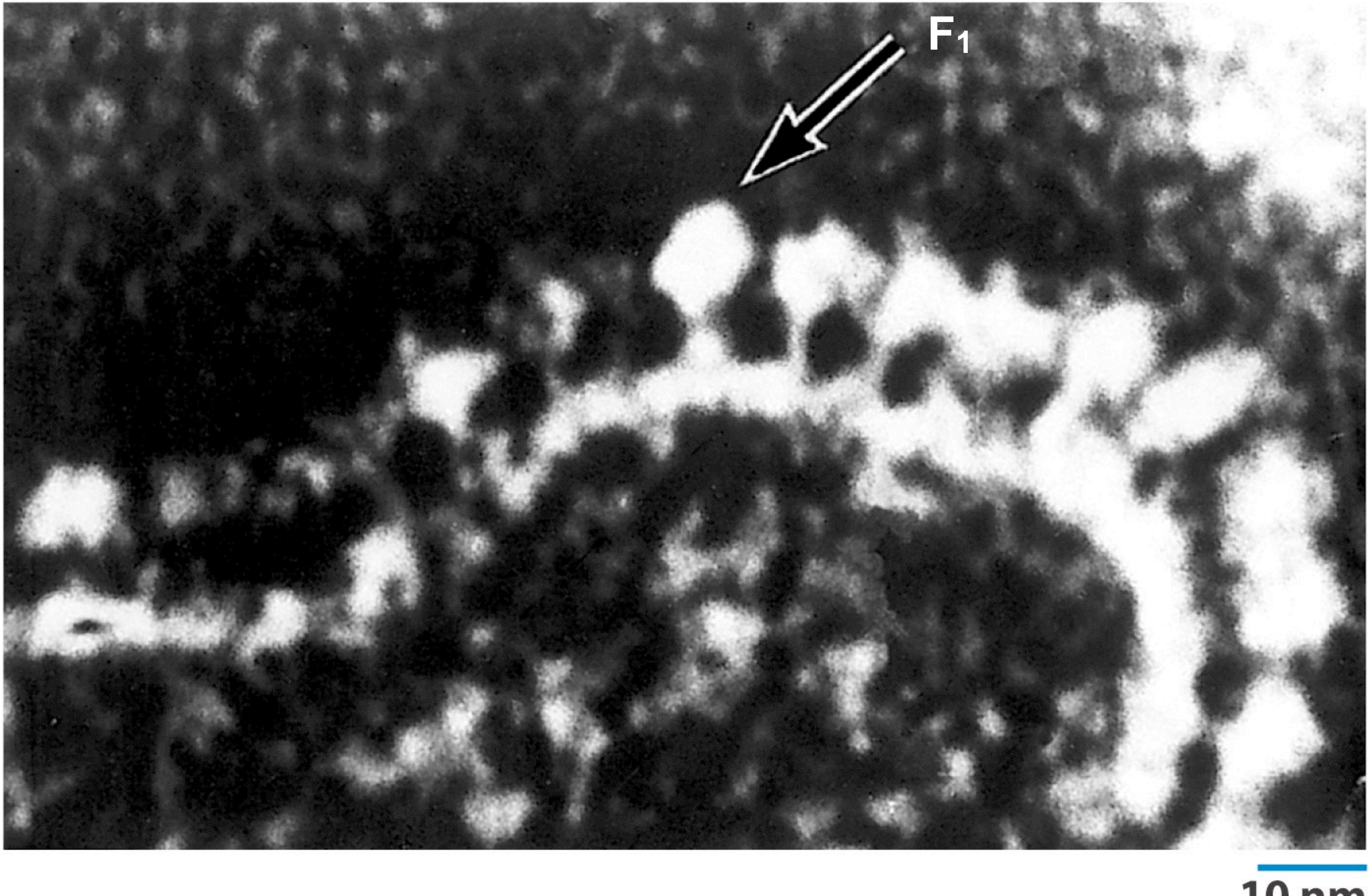
Memories of that call

F_o



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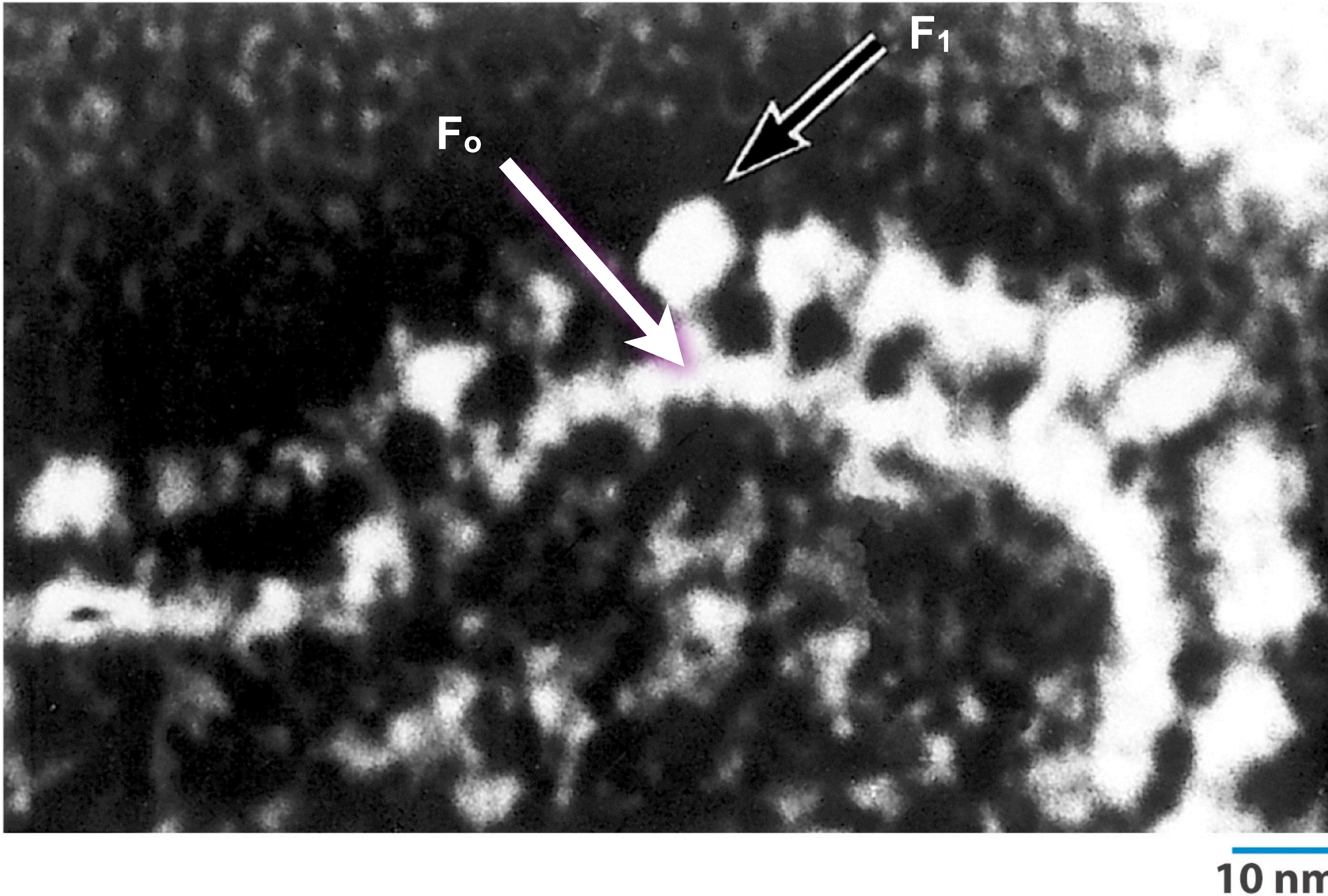

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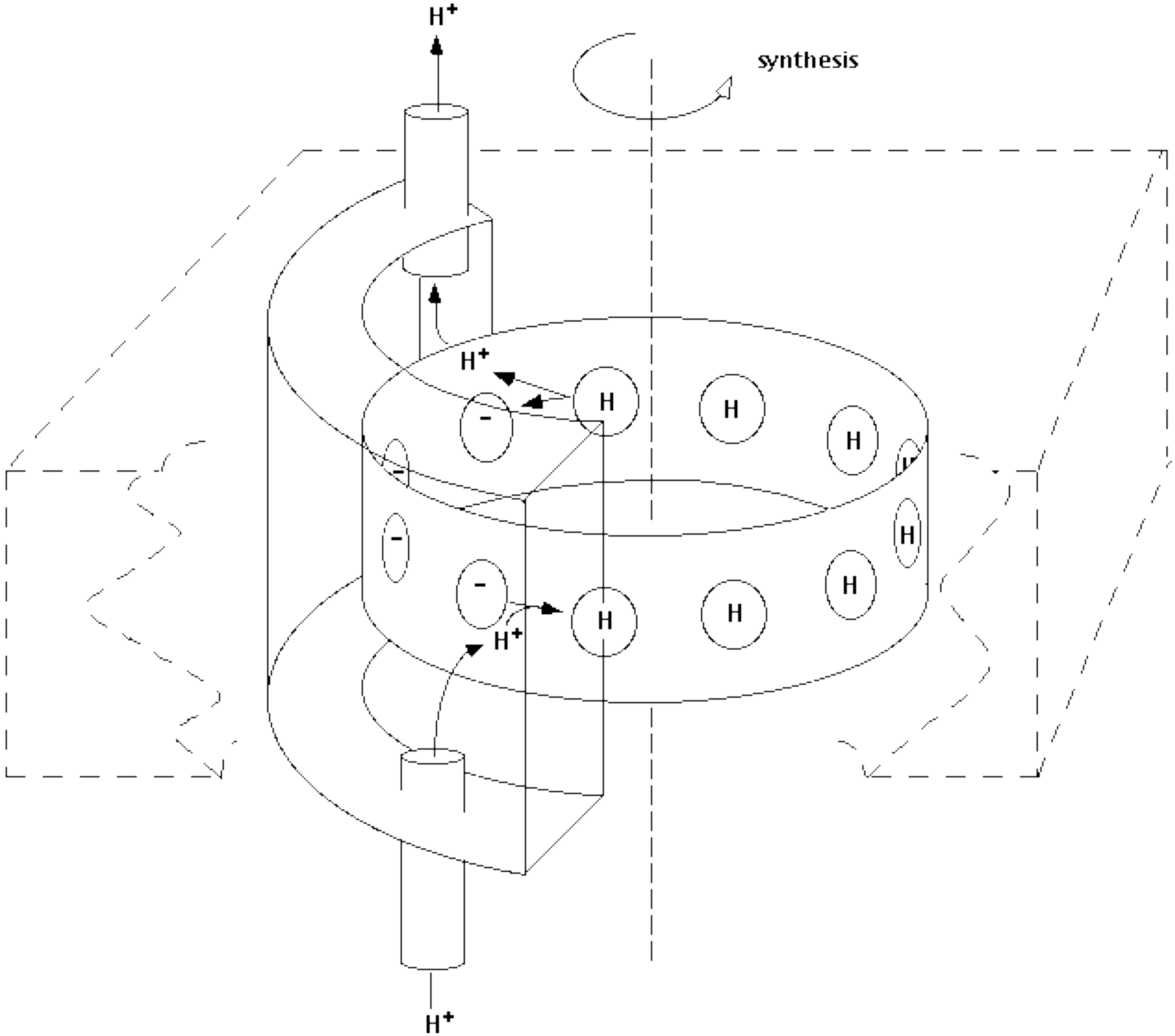
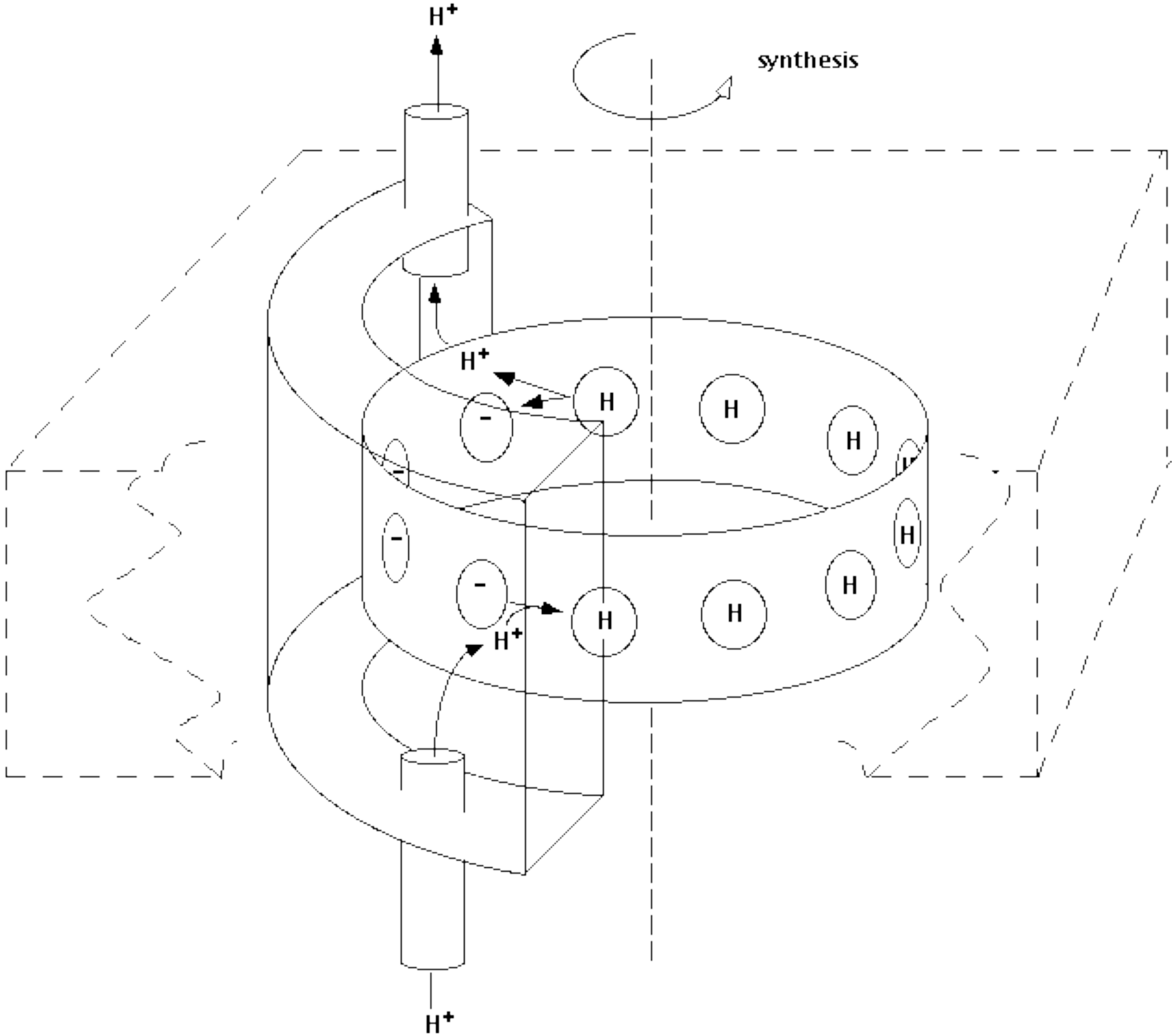
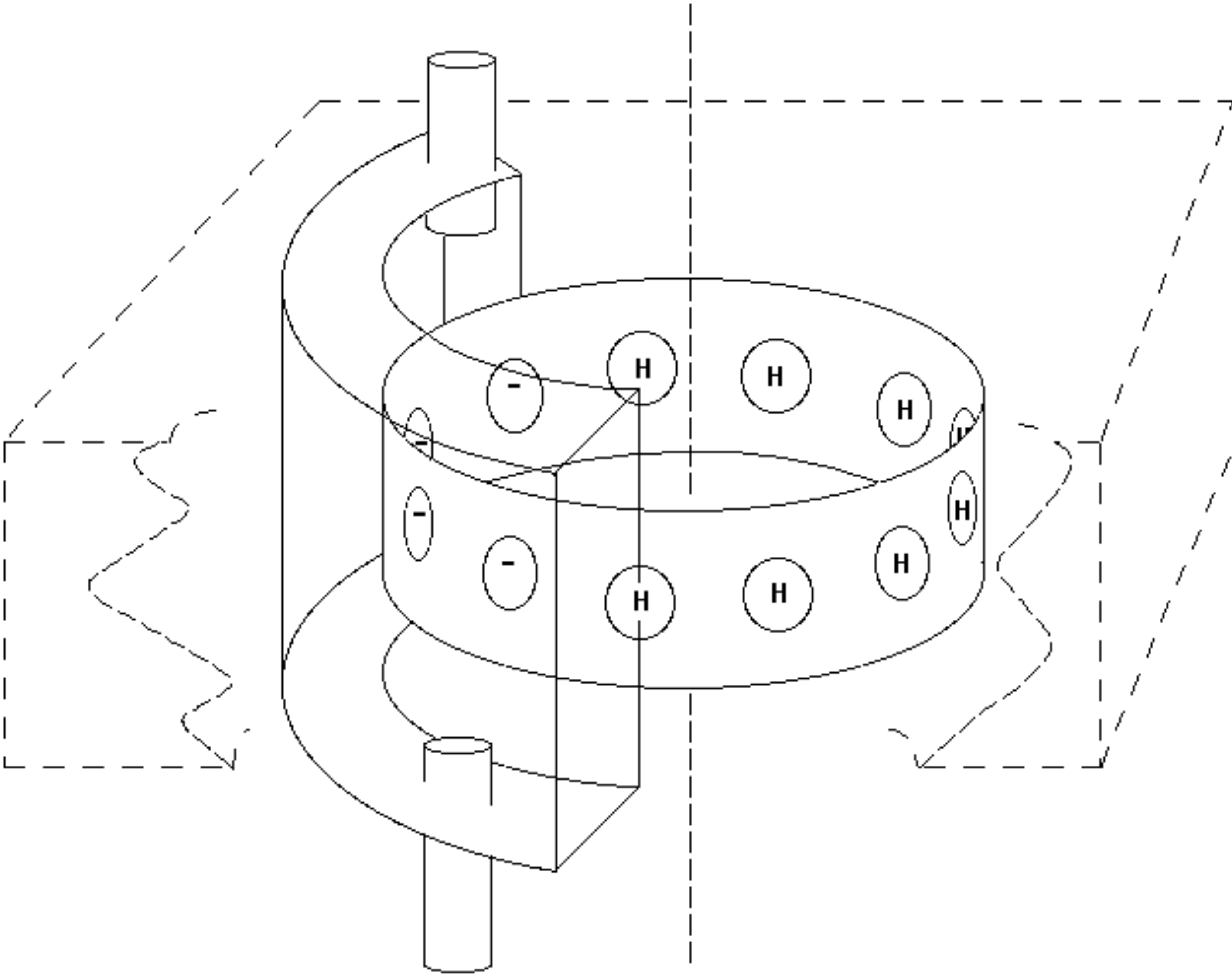


Rotation of the Fo-ATPase.Fo-ATPase as a proton-driven, rotary stepping motor, as proposed by Junge (1997).



Rotation of the Fo-ATPase.Fo-ATPase as a proton-driven, rotary stepping motor, as proposed by Junge (1997).

http://jfa.sbcs.qmul.ac.uk/~john/webstar/ltm/06/3ATP.html



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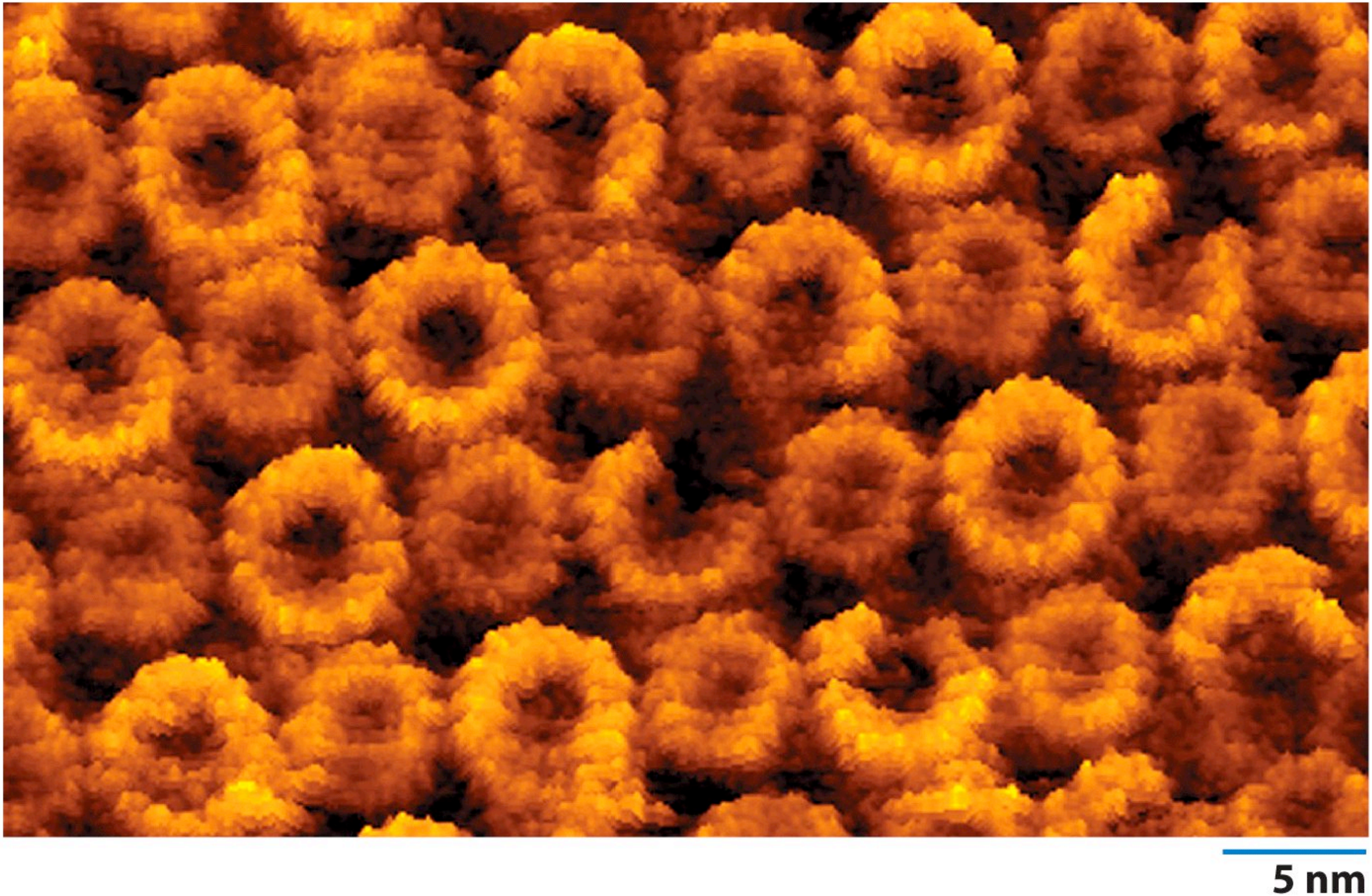

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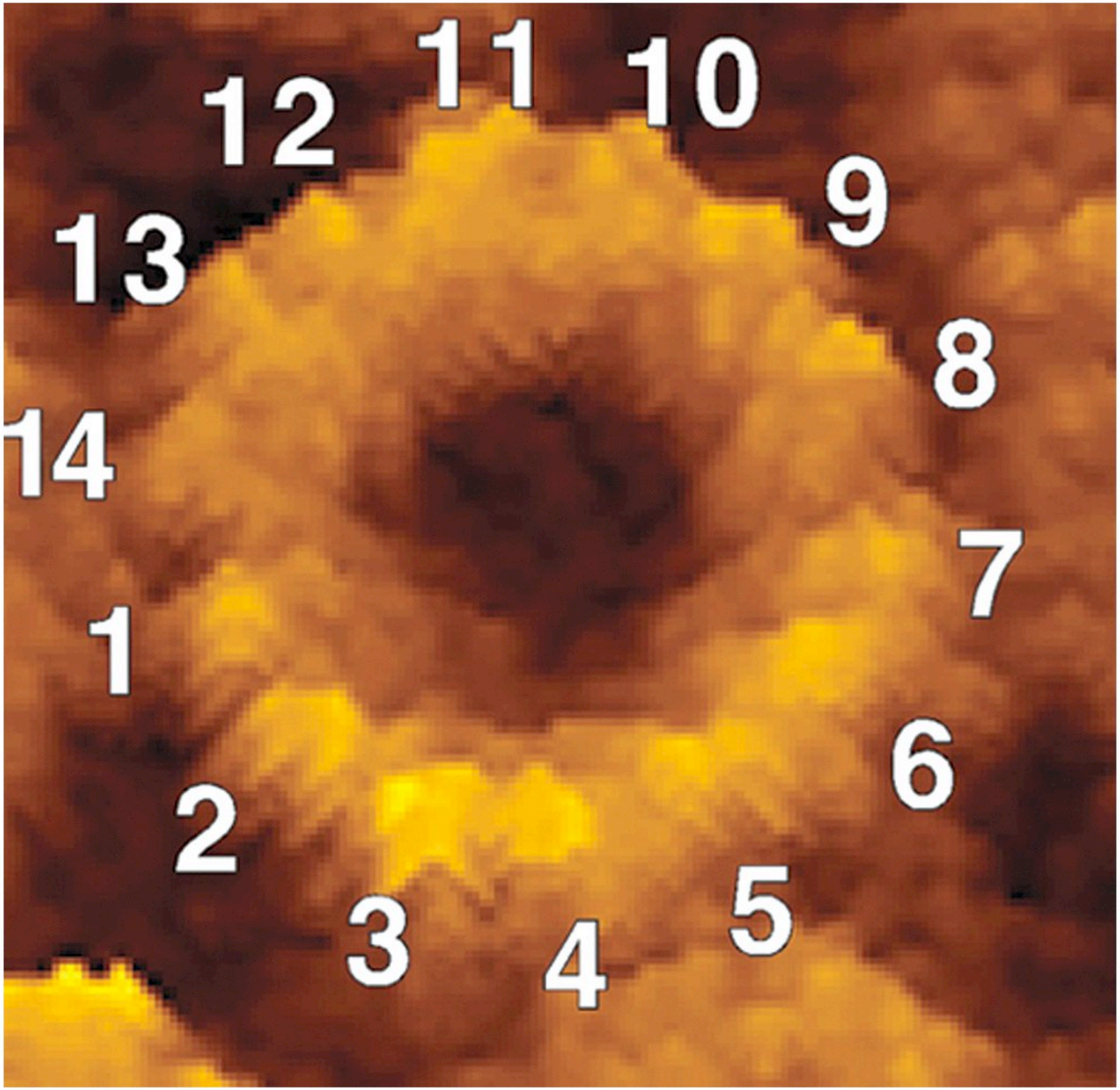

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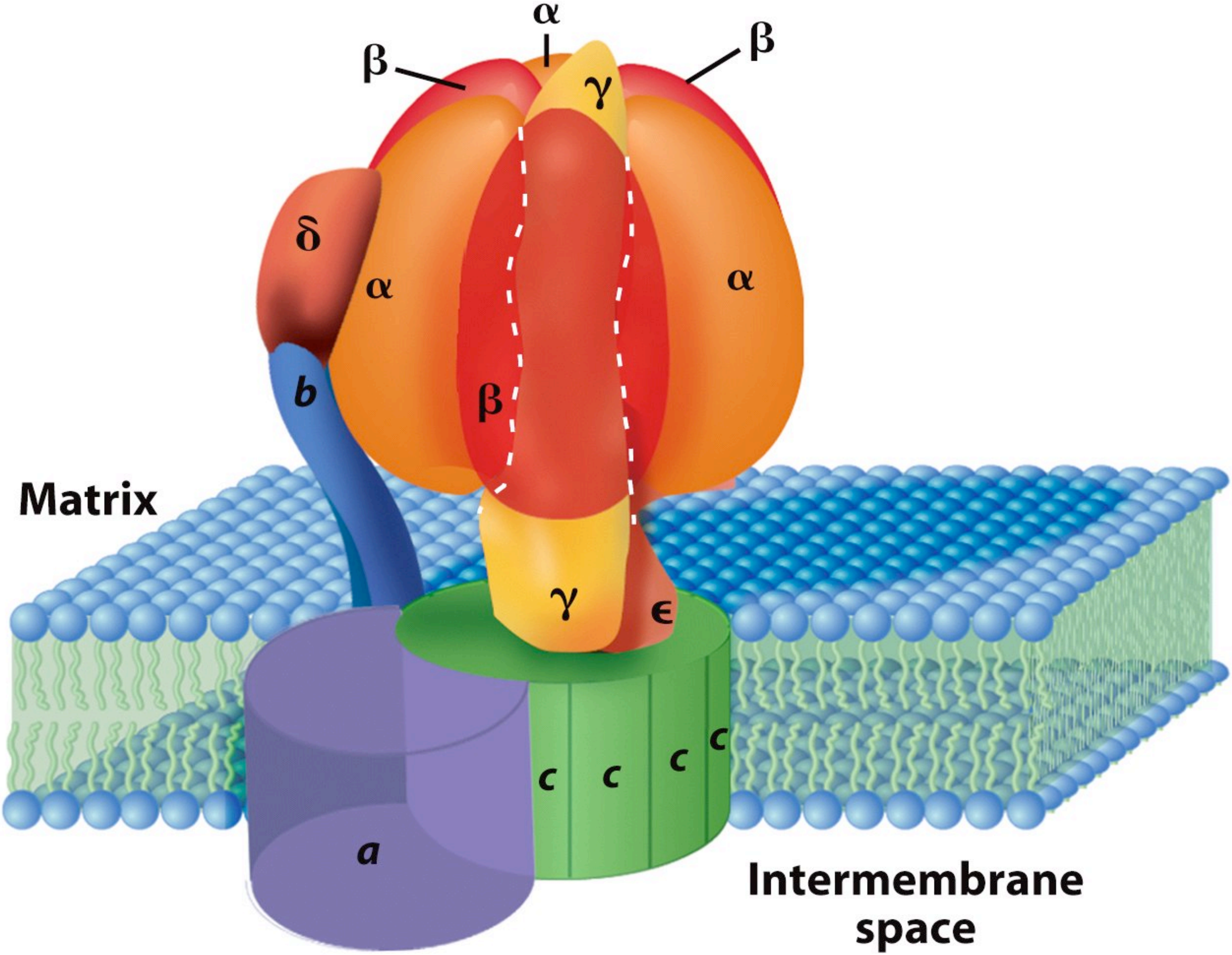
The F_1-F_o ATPase



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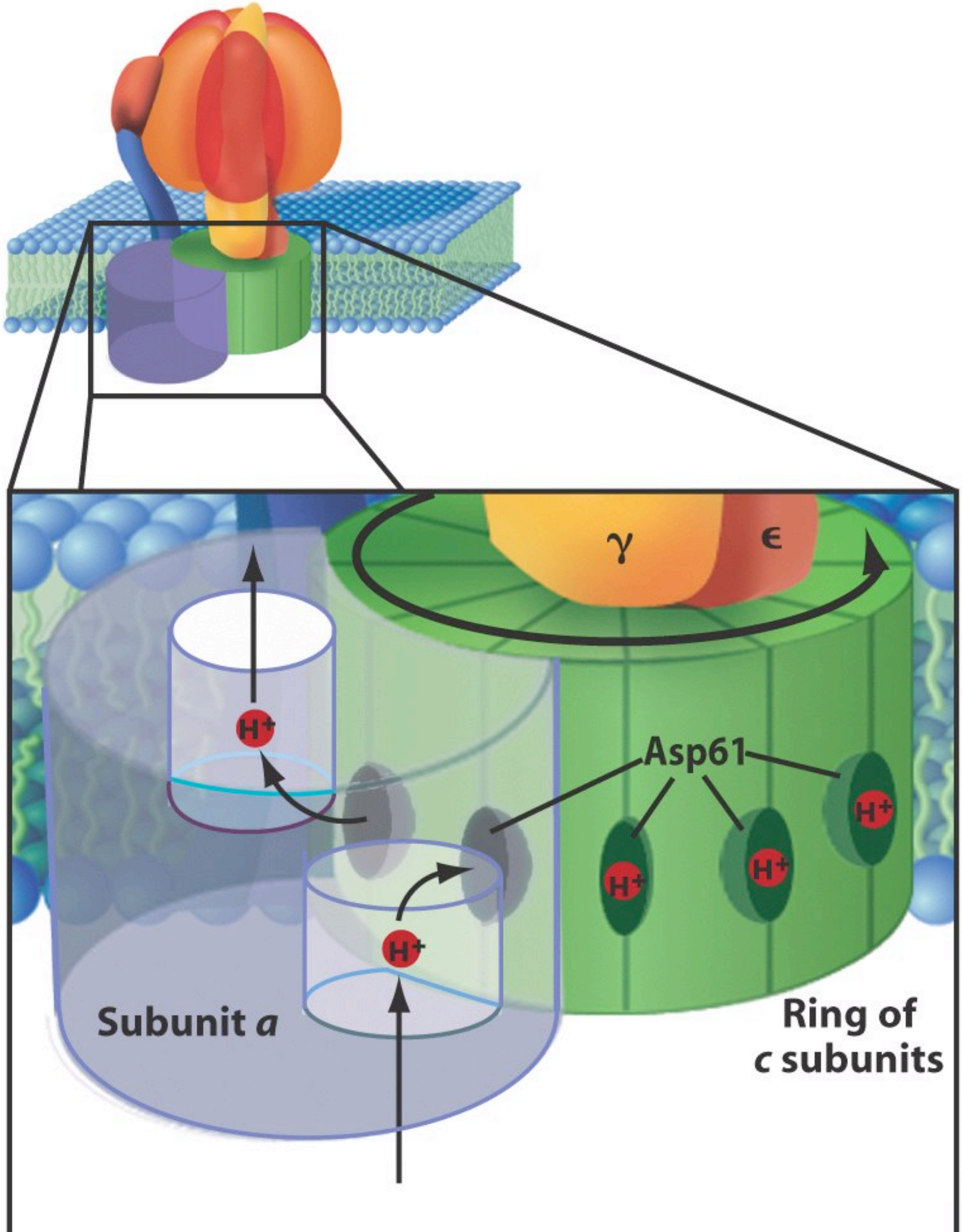

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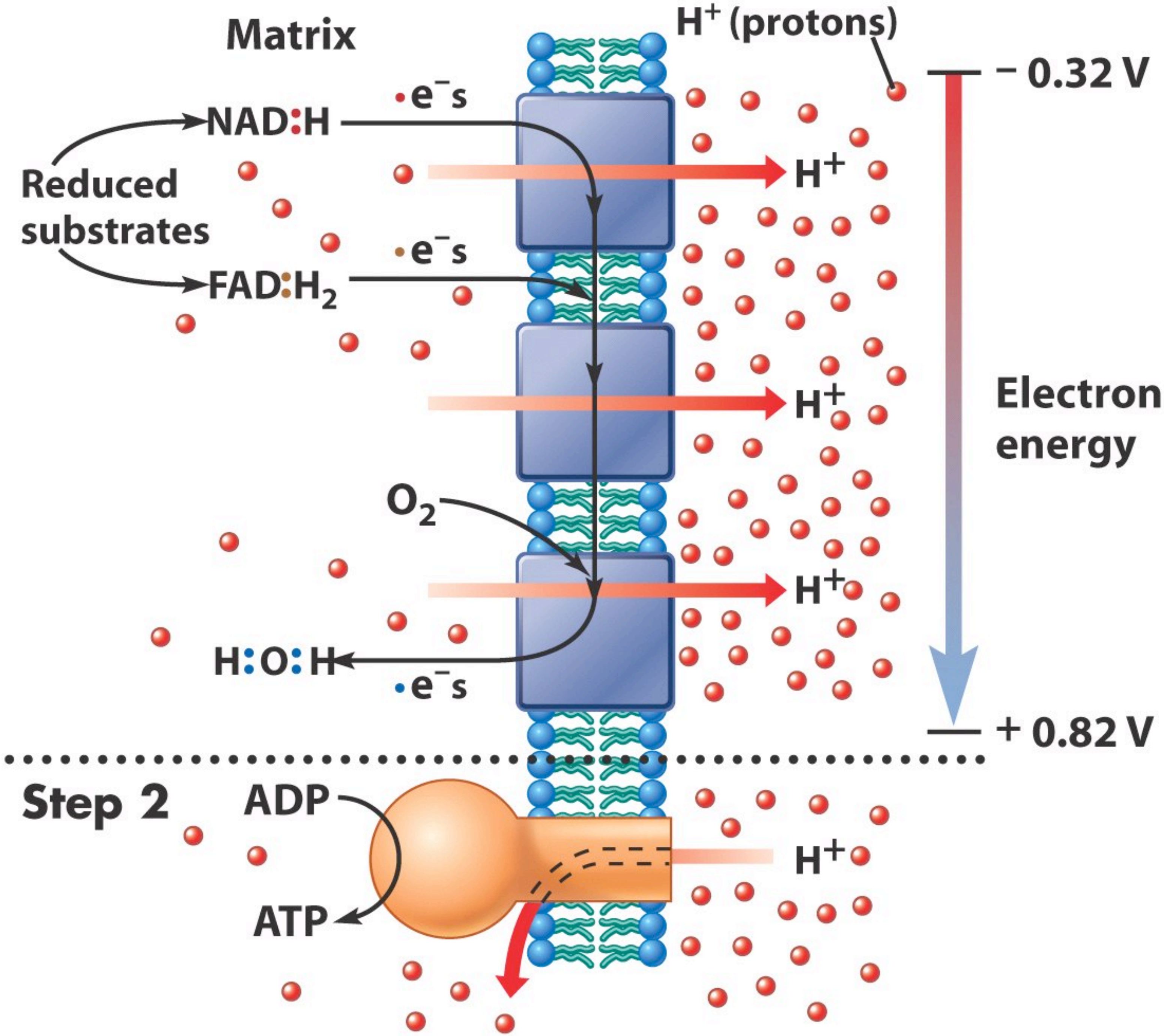

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Movies

These movies were created by Said Sannuga in collaboration with John Walker and Andrew Leslie.

http://www.mrc-mbu.cam.ac.uk/research/atp-synthase/molecular-animations-atp-synthase

Movies

These movies were created by Said Sannuga in collaboration with John Walker and Andrew Leslie.

- View from above and then below the F_1 domain along the rotating γ-subunit

http://www.mrc-mbu.cam.ac.uk/research/atp-synthase/molecular-animations-atp-synthase

Movies

These movies were created by Said Sannuga in collaboration with John Walker and Andrew Leslie.

- View from above and then below the F_1 domain along the rotating γ-subunit

- How the rotating γ-subunit imposes the conformational states on a β subunit required for substrate binding, ATP formation and ATP release

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Movies

These movies were created by Said Sannuga in collaboration with John Walker and Andrew Leslie.

- View from above and then below the F_1 domain along the rotating γ-subunit

- How the rotating γ-subunit imposes the conformational states on a β subunit required for substrate binding, ATP formation and ATP release

- Three conformations of a catalytic β-subunit produced by 120º rotations of the central γ-subunit

http://www.mrc-mbu.cam.ac.uk/research/atp-synthase/molecular-animations-atp-synthase

Movies

These movies were created by Said Sannuga in collaboration with John Walker and Andrew Leslie.

- View from above and then below the F_1 domain along the rotating γ-subunit

- How the rotating γ-subunit imposes the conformational states on a β subunit required for substrate binding, ATP formation and ATP release

- Three conformations of a catalytic β-subunit produced by 120º rotations of the central γ-subunit

- Changes in the positions of sidechains in the catalytic site of F_1-ATPase bringing about binding and subsequent hydrolysis of ATP

http://www.mrc-mbu.cam.ac.uk/research/atp-synthase/molecular-animations-atp-synthase

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The rotary catalytic mechanism of mitochondrial ATP synthase.

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Thank you for listening

Membrane Biochemistry

Lectures by

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