

Subsystem: Terminal cytochrome oxidases

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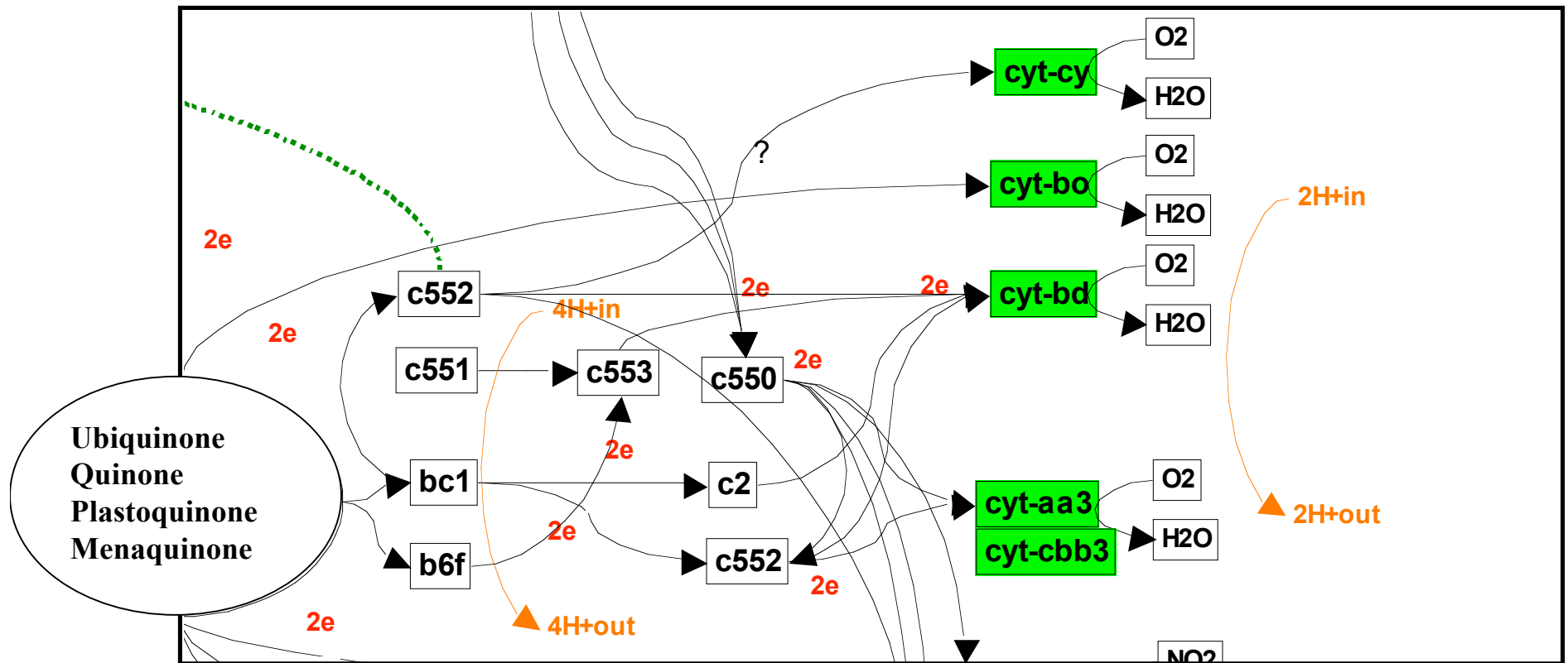
Abbrev	Functional Role
TPC	Transport ATP-binding protein cydC
TPD	Transport ATP-binding protein cydD
CydA	Cytochrome d ubiquinol oxidase subunit I (EC 1.10.3.-)
CydB	Cytochrome d ubiquinol oxidase subunit II (EC 1.10.3.-)
CyoA	Cytochrome O ubiquinol oxidase subunit II (EC 1.10.3.-)
CyoB	Cytochrome O ubiquinol oxidase subunit I (EC 1.10.3.-)
CyoC	Cytochrome O ubiquinol oxidase subunit III (EC 1.10.3.-)
CyoD	Cytochrome O ubiquinol oxidase subunit IV (EC 1.10.3.-)
AA3-600I	AA3-600 quinol oxidase subunit I
AA3-600II	AA3-600 quinol oxidase subunit II
AA3-600III	AA3-600 quinol oxidase subunit III
AA3-600IV	AA3-600 quinol oxidase subunit IV
TPCD	Transport ATP-binding protein cydCD
QxtI	putative Cytochrome bd2, subunit I
QxtII	putative Cytochrome bd2, subunit II

Subset	
cytochrome_bd2_complex	14,15
cytochrome_bd_complex_lowO2	3,4
cytochrome_bo_complex_highO2	5,6,7,8
cytochrome_caa3_complex	9,10,11,12
required_for_bd_expr	1,2,13

- In many bacteria the electron transport is highly diversified and there is more than one terminal respiratory oxidase. Different combinations of these complexes can be present in one organism. Terminal cytochrome oxidases exchange electrons either with the quinone pool or directly with cytochromes, depending on their redox potential.*
- The best-characterized terminal oxidases are those that are homologous to the aa3-type cytochrome c oxidases of mitochondria. The latter and bb3 (alternative) types of terminal oxidases are included in the Subsystem 'Terminal cytochrome c oxidases' and are excluded from this subsystem arbitrary because of the high volume of functional roles in both subsystems. Here we include cytochrome bo, bd, its variation bd2, and caa3 complexes. The subsystem is studied and annotated in all SEED organisms. About 15 variant codes corresponding to observed combinations are defined*
- An operational variant of this subsystem can be asserted in 330 out of 350 included organisms*

Subsystem diagram (fragment)

Part of the respiratory chain diagram illustrating the role of terminal oxidases in respiration



Subsystem Spreadsheet (a fragment)

Examples of functional variants and multiprotein complexes

Organism	Variant Code	TPC	TPD	CydA	CydB	CyoA	CyoB	CyoC	CyoD	AA3-600I	AA3-600II	AA3-600III	AA3-600IV
Synechocystis sp. PCC 6803 [B]	1	?	?	606	607								
Anabaena variabilis ATCC 29413 [B]	1	?	?	1553 , 3834 , 4043 , 4046	1555 , 4044 , 4045								
Bacillus subtilis subsp. subtilis str. 168 [B]	2	3879	3878	3074 , 3881	3880					3821	3822	3820	3819
Mycobacterium tuberculosis CDC1551 [B]	3	1703	1704	1706	1705								
Escherichia coli CFT073 [B]	4	995	996	1087 , 784	1088 , 785	521	520	519	518				
Proteus mirabilis HI4320 [B]	11	2010	2011	1168	1169	916 , 917	2672 , 918	2673	2674	2126 , 815	2127 , 816		
Pseudomonas aeruginosa PAO1 [B]	15					1318	1319	1320	1321	3929	3928		

caa3

bd

bo

bd2

Function?
Missing?
next slide

Open questions, comments, conjectures

- *Cytochrome complex bd is composed of the two main subunits CydA and CydB, but in the majority of organisms it requires additional proteins CydD and CydC for its expression.*
- *Function of CydC,D is not clear, although they belongs to a family of ATP-binding cassette transporters. In E.coli CydCD has been shown to transports cysteine, which is crucial for redox homeostasis in the periplasm (Pittman et al., 2002).*
- *In B. subtilis overexpression of cydAB alone does not lead to production of functional cytochrome bd complex even in a CydD mutant strain (Winstedt et al, 1998). Potential function of these additional subunits in Gram positive organisms remains a mystery.*
- *CydD, and CydC subunits are missing in some organisms, e.g. cyanobacteria. It is not clear though, if they are required for a functional bd complex in these particular organisms. The so called bd2 complex (homologous to bd) seems to not require CydC or CydD:*
 - *no clear homologs of known CydC,D subunits can be asserted in these organisms*
 - *the corresponding gene clusters do not include any putative transporters - potential gene candidates for the CydD and CydC functional roles*
- *Can it be that all CydC,D-less bd complexes are actually bd2 ones? Is it just a matter of terminology or a meaningful difference between the bd and bd2 complexes?*