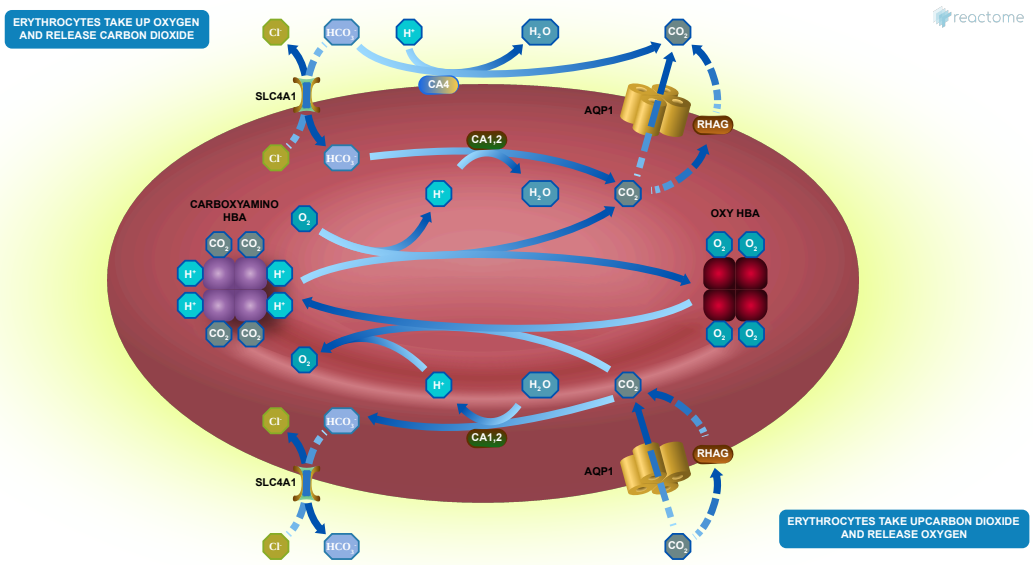
O2/CO2 exchange in erythrocytes



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Introduction

Reactome is open-source, open access, manually curated and peer-reviewed pathway database. Pathway annotations are authored by expert biologists, in collaboration with Reactome editorial staff and cross-referenced to many bioinformatics databases. A system of evidence tracking ensures that all assertions are backed up by the primary literature. Reactome is used by clinicians, geneticists, genomics researchers, and molecular biologists to interpret the results of high-throughput experimental studies, by bioinformaticians seeking to develop novel algorithms for mining knowledge from genomic studies, and by systems biologists building predictive models of normal and disease variant pathways.
The development of Reactome is supported by grants from the US National Institutes of Health (P41 HG003751), University of Toronto (CFREF Medicine by Design), European Union (EU STRP, EMI-CD), and the European Molecular Biology Laboratory (EBI Industry program).

Literature references

Fabregat, A., Sidiropoulos, K., Viteri, G., Forner, O., Marin-Garcia, P., Arnau, V. et al. (2017). Reactome pathway analysis: a high-performance in-memory approach. *BMC bioinformatics, 18*, 142. ↗

Sidiropoulos, K., Viteri, G., Sevilla, C., Jupe, S., Webber, M., Orlic-Milacic, M. et al. (2017). Reactome enhanced pathway visualization. *Bioinformatics, 33*, 3461-3467. ↗

Fabregat, A., Jupe, S., Matthews, L., Sidiropoulos, K., Gillespie, M., Garapati, P. et al. (2018). The Reactome Pathway Knowledgebase. *Nucleic Acids Res, 46*, D649-D655. ↗

Fabregat, A., Korninger, F., Viteri, G., Sidiropoulos, K., Marin-Garcia, P., Ping, P. et al. (2018). Reactome graph database: Efficient access to complex pathway data. *PLoS computational biology, 14*, e1005968. ↗

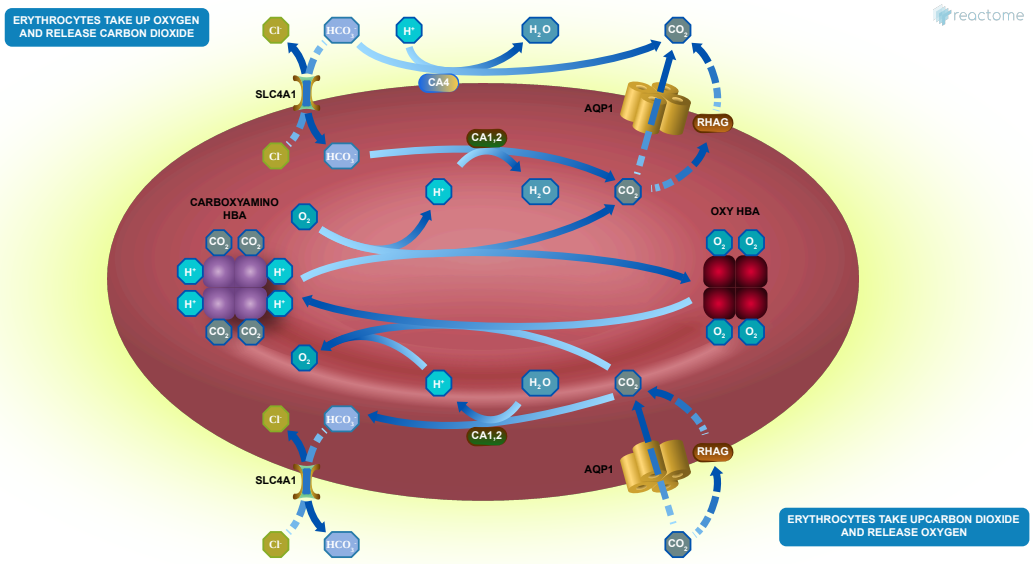
Reactome database release: 88

This document contains 3 pathways (see Table of Contents)

O2/CO2 exchange in erythrocytes ↗

Stable identifier: R-HSA-1480926

Compartments: cytosol, extracellular region, plasma membrane



In capillaries of the lungs Erythrocytes take up oxygen and release carbon dioxide. In other tissues of the body the reverse reaction occurs: Erythrocytes take up carbon dioxide and release oxygen (reviewed in Nikinmaa 1997, Jensen 2004).
In the lungs, carbon dioxide (CO2) bound as carbamate to the N-terminus of hemoglobin (HbA) and protons bound to histidine residues in HbA are released as HbA binds oxygen (O2). Bicarbonate (HCO3-) present in plasma is taken up by erythrocytes via the band3 anion exchanger (AE1, SLC4A1) and combined with protons by carbonic anhydrases I and II (CA1, CA2) to yield water and CO2 (reviewed by Esbaugh & Tufts 2006, De Rosa et al. 2007). The CO2 is passively transported out of the erythrocyte by AQP1 and RhAG. HCO3- in plasma is also directly dehydrated by extracellular carbonic anhydrase IV (CA4) present on endothelial cells lining the capillaries in the lung.
In non-pulmonary tissues CO2 in plasma is hydrated to yield protons and HCO3- by CA4 located on the apical plasma membranes of endothelial cells. Plasma CO2 is also taken up by erythrocytes via AQP1 and RhAG. Within erythrocytes CA1 and, predominantly, CA2 hydrate CO2 to yield HCO3- and protons (reviewed in Geers & Gros 2000, Jensen 2004, Boron 2010). HCO3- is transferred out of the erythrocyte by the band 3 anion exchange protein (AE1, SLC4A1) which cotransports a chloride ion into the erythrocyte.
Also within the erythrocyte, CO2 combines with the N-terminal alpha amino groups of HbA to form carbamates while protons bind histidine residues in HbA. The net result is the Bohr effect, a conformational change in HbA that reduces its affinity for O2 and hence assists the delivery of O2 to tissues.

Literature references

Jensen, FB. (2004). Red blood cell pH, the Bohr effect, and other oxygenation-linked phenomena in blood O2 and CO2 transport. *Acta Physiol Scand, 182*, 215-27. ↗

Carelli Alinovi, C., De Rosa, MC., Scatena, R., Giardina, B., Galtieri, A. (2007). The plasma membrane of erythrocytes plays a fundamental role in the transport of oxygen, carbon dioxide and nitric oxide and in the maintenance of the reduced state of the heme iron. *Gene, 398*, 162-71. ↗

Gros, G., Geers, C. (2000). Carbon dioxide transport and carbonic anhydrase in blood and muscle. *Physiol Rev, 80*, 681-715. ↗

Boron, WF. (2010). Evaluating the role of carbonic anhydrases in the transport of HCO3--related species. *Biochim Biophys Acta, 1804*, 410-21. ↗

Nikinmaa, M. (1997). Oxygen and carbon dioxide transport in vertebrate erythrocytes: an evolutionary change in the role of membrane transport. *J Exp Biol, 200,* 369-80. ↗

Editions

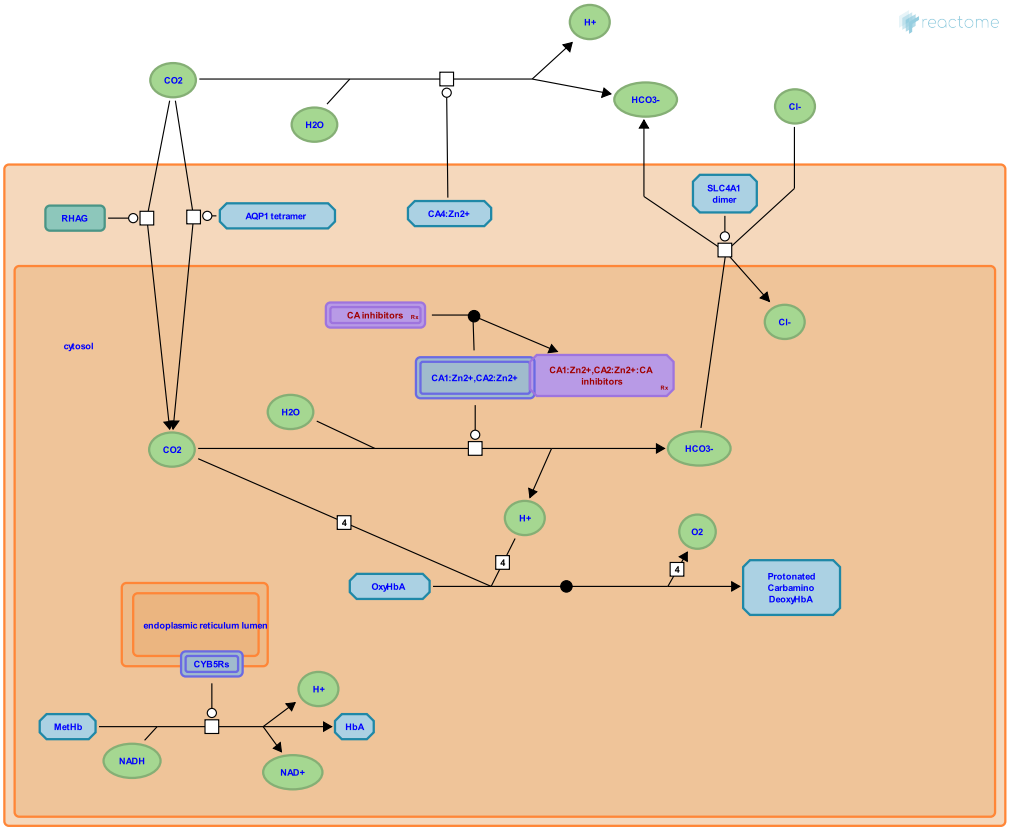
2011-11-01	Authored, Edited	May, B.
2012-04-27	Reviewed	Jassal, B.

Erythrocytes take up carbon dioxide and release oxygen ↗

Location: O2/CO2 exchange in erythrocytes

Stable identifier: R-HSA-1237044

Compartments: plasma membrane, extracellular region, cytosol



Carbon dioxide (CO2) in plasma is hydrated to yield protons (H+) and bicarbonate (HCO3-) by carbonic anhydrase IV (CA4) located on the apical plasma membranes of endothelial cells. Plasma CO2 is also taken up by erythrocytes via AQP1 and RhAG. Within erythrocytes CA1 and, predominantly, CA2 hydrate CO2 to HCO3- and protons (reviewed in Geers & Gros 2000, Jensen 2004, Boron 2010). The HCO3- is transferred out of the erythrocyte by the band 3 anion exchange protein (AE1, SLC4A1) which cotransports a chloride ion (Cl-) into the erythrocyte.
Also within the erythrocyte, CO2 combines with the N-terminal alpha amino groups of HbA to form carbamates while protons bind histidine residues in HbA. The net result is the Bohr effect, a conformational change in HbA that reduces its affinity for O2 and hence assists the delivery of O2 to tissues.

Literature references

Jensen, FB. (2004). Red blood cell pH, the Bohr effect, and other oxygenation-linked phenomena in blood O2 and CO2 transport. *Acta Physiol Scand, 182*, 215-27. ↗

Gros, G., Geers, C. (2000). Carbon dioxide transport and carbonic anhydrase in blood and muscle. *Physiol Rev, 80*, 681-715. ↗

Boron, WF. (2010). Evaluating the role of carbonic anhydrases in the transport of HCO3--related species. *Biochim Biophys Acta, 1804*, 410-21. ↗

Editions

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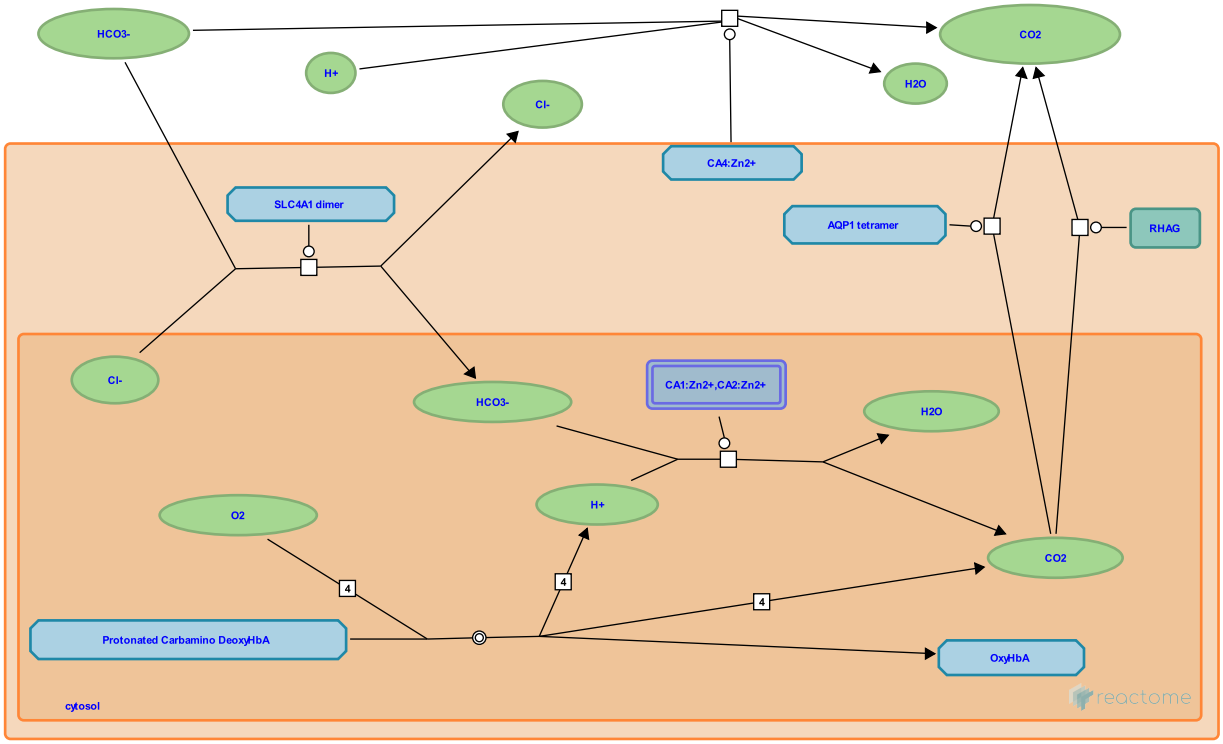
2012-04-27	Reviewed	Jassal, B.

Erythrocytes take up oxygen and release carbon dioxide ↗

Location: O2/CO2 exchange in erythrocytes

Stable identifier: R-HSA-1247673

Compartments: plasma membrane, extracellular region, cytosol



Erythrocytes circulating through the capillaries of the lung must exchange carbon dioxide (CO2) for oxygen (O2) during their short (0.5-1 sec.) transit time in pulmonary tissue (Reviewed in Jensen 2004, Esbaugh and Tufts 2006, Boron 2010). CO2 bound as carbamate to the N-terminus of hemoglobin and protons (H+) bound to histidine residues in hemoglobin are released as hemoglobin (HbA) binds O2. Bicarbonate (HCO3-) present in plasma is taken up by erythrocytes via the band3 anion exchanger (AE1, SLC4A1) and combined with H+ by carbonic anhydrases I and II (CA1/CA2) to yield water and CO2 (Reviewed by Esbaugh and Tufts 2006). CO2 is passively transported out of the erythrocyte by AQP1 and RhAG. HCO3- in plasma is also directly dehydrated by extracellular carbonic anhydrase IV (CA4) present on endothelial cells lining the capillaries in the lung.

Literature references

Jensen, FB. (2004). Red blood cell pH, the Bohr effect, and other oxygenation-linked phenomena in blood O2 and CO2 transport. *Acta Physiol Scand, 182*, 215-27. ↗

Boron, WF. (2010). Evaluating the role of carbonic anhydrases in the transport of HCO3--related species. *Biochim Biophys Acta, 1804*, 410-21. ↗

Tufts, BL., Esbaugh, AJ. (2006). The structure and function of carbonic anhydrase isozymes in the respiratory system of vertebrates. *Respir Physiol Neurobiol, 154*, 185-98. ↗

Editions

2011-04-04	Authored, Edited	May, B.
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