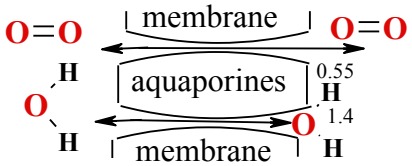
IUBMB Life Volume 61, Issue 2, pages 112–133, February 2009© **Water channels H_2O and O_2,NO,CO:an overview**

3M9I **1YMG** **AQP0** **2B6O** **1SOR**	+ Cl^-, NO_3^- **eye-lens cells**; thin **junctions** between **fibre cells** **AQP0** with a measured **Water permeability** 15-fold lower than that of **AQP1** at **pH 6.5**; **AQP0** is reduced a further three fold at **pH 7.5** **AQP0** induce a gating effect **close** conformations of extra**cell**ular **loop** A **Met176**,**His40** **AQP0** becomes more **constrained** near the **conserved Ar/R constriction** site
H6I **1J4N** **AQP1-** **1IH5** **1FQY**	**pH's** below **5.5** Cl^-, NO_3^-,Aqua**glycero**porins:**red blood cell** (RBC), **Cation conduct**ance has been induced in **AQP1** by activation of cyclic **GMP**–dependent pathways. **Water conduct**ance was blocked by Hg^{2+} apical & basolateral **membranes** of **epithelial** brain **cell**, **rodent brain cell** **AQP1**-null humans **kidney** proximal-tubule **water** reabsorption **gastrointestin**al tract **Water** absorption in the teleost **intestine** the ovary and in the oocyte ; salivary gland ;
AQP2	urinary bladder granular **kidney cell**s & sub**cell**ular vasopressin regulated urine concentration (~25% of the **blood** filtrate) **trans**located from the cytoplasmic pool to the apical plasma **membrane** of the granular **cell**s of the pelvic patch and urinary bladder
AQP3	+Aqua**glycero**porins,urea:**gastrointestin**al tract **Water** absorption**;rodent brain cell** astrocyte end-feet **Water** enters in the principal **cell** through **AQP**2 and exits through located in the basolateral **membrane**s trachea **kidney**(basolaterally) basal **AQP**3 & ciliated columnar **AQP**4 **cell**s
AQP4	**Rodent-**brain;basolateral **membrane** of ciliated columnar **cell**s alveolar epithelium;salivary gland **kidney**(basolaterally) **3IYZ, 2D57, 3GD8**
3D9S AQP5	stomach, duodenum, pancreas, airways, lungs, salivary gland, sweat glands, eyes, lacrimal glands, and the inner ear tears & pulmonary submucosal glands secretions apical **membrane**& **rodent brain cell**s,**gating** is lacking
AQP6	+ Cl^- , NO_3^- multipermeable **channel;lens cell**s; may play a **role** in the body acid–base **homeostasis** in the intra**cell**ular vesicles of acid-secreting intercalated **cell**s of the RCD colocalized with the H^+-ATPase be Hg^{2+}-inhibitable **Water channel** function is activated by Hg^{2+} and low **pH**
1FX8 AQP7 1LDF	**GLPF** Aqua**glycero**porins, urea; **kidney** proximal tubule **epithelium cell** **glycerol** reabsorption; together with **AQP1** in the brush border in the concentration of urine taking place in the proximal **nephron** cells ~75% of the **blood** filtrate which is ~150–180 L per day
AQP8	NH_4^+;**lens** & **kidney** intra**cell**ularly proximal tubule & small **intestine** absorptive:**epithelium cell** in the concentration of urine taking place in the proximal nephron also in mitochondria ~75% of the **blood** filtrate which is ~150–180 L per day & **rodent brain cell**
AQP9	+Aqua**glycero**porins, urea purines, pyrimidines & monocarboxylates, arsenite ; apical **membrane** of brain & small **intestine** absorptive epithelial & rodent **brain** & glial **cell**s
AQP10	+ Aqua**glycero**porins, urea ; small **intestine** absorptive epithelial **cell**s
AQP11	"super**aquaporin**s" or sub**cell**ular; **kidney** cytoplasm of the proximal tubule & **rodent brain cell**s
AQP12	"super**aquaporin**s" or sub**cell**ular
AQPM	Archaebacterial **2EVU, 2F2B, 3NE2, 3NE20**
AQPIP	Plant **pore opening** and **closing 1Z98, 2B5F, 3CN6, 4IA4, 4JC6**
1RC2 AQPZ	**3ZOJ**; Escherichia coli: **Arg189** "upwards" extra**cell**ular **Water channel** is **open** **2ABM, 2O9G, 3NK5, 3NKA, 3NKC, Arg189** "downwards" into **pore** & **closes** the **channel**
Fchann	Formate: **3KCU, 3KLY, 3Q7K** H_2O **Channel** is roughly **20-Å long** and has a diameter **1.1 Å**. **Water channel** proteins



bilipid membrane cross size **55Å**

(**WCPS**s) are **trans membrane** proteins that have a specific three-dimensional structure with a **pore** the **SF radius ~1.1** *Å* is close average **to radius** of **water H–O–H** longetudinal **1.4** Å and **0.55 Å** bent size of dipole.

It can be permeated by **Water** & O_2, **NO**, **CO** molecules as solutes. **Aquaporins** are large families (over 450 members) that are present in all kingdoms of life. **Water permeability**, allowing permeation of **3 × 10^9 water** molecules per **monomer** per second **AQP1** and other, which strictly prevents the **conduction** of protons H^+.

Serine, Tyrosine, Threonine **AQP**8, and the gating of **AQP**4.

Phosphorylation to trigger the **membrane traffic**king of **AQP1**, **AQP**2, **AQP**5, and **Cation conduct**ance has been induced in **AQP1** by activation of cyclic **GMP**–dependent pathways and was blocked by Hg^{2+}

membrane channels represent fast phenomena on the order of **nanoseconds**

AQP1 Mol Biol Evol *(2011) 28 (11): 3151-3169.* Volume 28,, Issue 11 Pp. 3151-3169. **1J4N 1J4N**

AQP0 **1TM8>superSeed>1YMG 2B5F** (2004) Proc.Natl.Acad.Sci.USA **101:** 14045-14050

HET BNG A 801 21 **1J4N** AQP1 Mol Biol Evol *(2011) 28 (11): 3151-3169*

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HET    BNG  A 802      21
HET    BNG  A 803      21

HETNAM     BNG B-NONYLGLUCOSIDE
FORMUL   2  BNG    3(C15 H30 O6)

FORMUL   5  HOH   *114(H2 O)

HELIX    1   1 PHE A    5  GLY A   34  1                                  30
HELIX    2   2 PHE A   35  TYR A   37  5                                   3
HELIX    3   3 ASP A   50  GLY A   74  1                                  25
HELIX    4   4 ASN A   78  SER A   88  1                                  11
HELIX    5   5 SER A   92  THR A  118  1                                  27
HELIX    6   6 GLY A  138  GLY A  140  5                                   3
HELIX    7   7 LEU A  141  THR A  159  1                                  19
HELIX    8   8 SER A  169  GLY A  190  1                                  22
HELIX    9   9 ASN A  194  THR A  205  1                                  12
HELIX   10  10 TRP A  212  PHE A  231  1                                  20
HELIX   11  11 ASP A  239  LYS A  245  1                                   7
HELIX   12  12 VAL A  246  THR A  248  5                                   3

SITE     1 AC1  2 VAL A 105  ILE A 108
SITE     1 AC2  4 PHE A 199  PHE A 208  HOH A 343  HOH A 364
SITE     1 AC3  4 ILE A 113  ILE A 117  GLN A 139  GLY A 142
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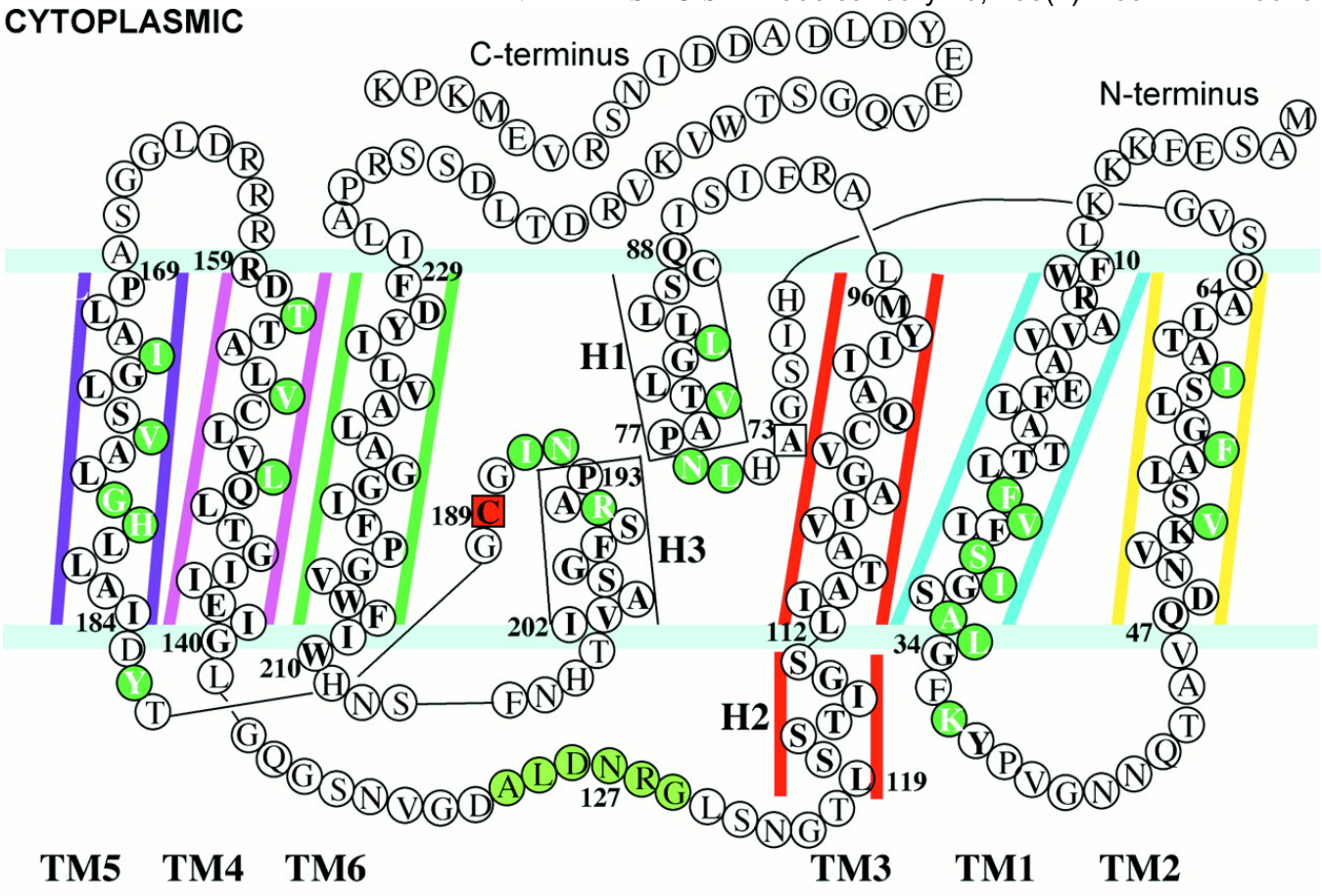
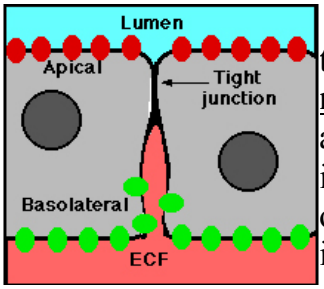
Proc Natl Acad Sci U S A. 2006 January 10; 103(2): 269–274. Biochemistry **1J4N**



IV. Water Conductance The **cell** have an incredibly large number of these **channels** (˜60% by weight of all **membrane** proteins in the **cell** plasma **membrane** is **AQP1,0 - 12**) by having

AQPs conduct water selectively. Thus, it ensures a uniform response to **osmotic homeostasis** challenge in all areas of the cell surfaces of the tightly packed cells throughout and maintains **homeostasis** of **water** [H_2O] = **55,3 M** and oxygen [O_2] = $6 \cdot 10^{-5}$ **M** in life systems.

WCPSs (AND OTHER **MIPs**) IN **SOME** MULTICELLULAR ANIMAL SPECIES WPCs have been discovered in **animals** at all levels of life, as well as in almost all organs and tissues of **human**s and a variety of **role**s have been documented or suggested. Selected examples are described below.



AQP1 is abundant in the apical and basolateral **membrane**s of epithelial cells in the proximal tubule and descending thin limb of Henle's **loop** (DTLH), and in the microvascular endothelium of outer medulary descending vasa recta (DVR). **AQP**7 and **AQP**8 are also present in the proximal tubule epithelium. These **WCPS**s are involved in the concentration of **urine** taking place in the proximal nephron (~75% of the **blood** filtrate which is 150–180 L per day)171. The functional **role** of **AQP**1 in **kidney** was confirmed by investigations on mice and **human**s.

Measurements of **water conduct**ance using oocyte and proteopositivelysome swelling demonstrate that **AQP0 water permeability** is **15**- to **45**-fold less than **AQP1. Water permeability AQP1**, allowing **permeation** 3×10^9 **water** molecules per **monomer** per second and per **tetramer** 12×10^9 per second. Published **water-permeability** data have varied from **0**- to **43**-fold over **conduction** through **lipid**s alone or through the **membrane**s of oocytes injected with **water**. Unfortunately, comparisons between published **conduction rate**s are difficult because they are generally relative **conduct**ances uncorrected for the number of **conduct**ing **channel**s, and they are also difficult because of the variety of materials and methods used.

A question arises as to the **channel** dimensions required for passage of various permeants through the **channel**. Use of the minimum diameter of the permeant as a rough measure of the **channel** diameter required for passage, as well as the diameter of the largest sphere that will fit in the **channel** at the **narrowest constriction** of the **channel**, provides one criterion. The diameter of the **channel** calculated in this way for a static structure would suggest that both of our structures of **AQP0 channel** (d = **1.5 Å**) and the Walz structures of **AQP0 channel** d=**2.0Å** are too **narrow** to permit the passage of **water** and other larger permeants, including **glycerol** and **urea**. Previous functional studies have shown significant measurable flux through **AQP0** of all three of these substances, even though some of these results are questionable. However, if the **channel** were to have a noncircular profile, then the available cross-sectional area could be larger than the value implied by this calculation. Further, the **channel** diameter values calculated for b**AQP0**, **AQP1**, and **AQPZ** are also all smaller than the accepted value of **2.8 Å** for the diameter of a single **water** molecule H_2O, yet all of these **AQPs conduct water** at close to the diffusion-limiting **rate**. Therefore, to test the possible accommodation of **AQP0** to these substrates, we selected side-chain **rotamers** of **constriction-region** residues of our **AQP0** structure that maximized **channel** diameter without any main chain movement. After extensive energy minimization and annealing, the resulting structures had stable **rotamers** that could enlarge the **channel** diameter to slightly >**2.9 Å**, which is more than large enough for **water** to pass. Additional circumstantial evidence of **water** transport is the presence of **eight Helix-bonded water** 8H_2O molecules in the **channel** (no **water**s are seen in the electron-diffraction structure). These **waters** are moderately well ordered, as reflected by their electron densities (Graph Center) and by their B factors, which are close to the average for the protein (?B? = 55) as follows: 57,57,54,51,48, 44,41, and 38, from extra**cell**ular to intra**cell**ular in the **channel**. Thus, there is **water** throughout the **channel** pathway (Graph).