

Fourth Phase Water
What is it?
Why it is so important?
Implications for treatment

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January 2025

Water – Exclusion Zone (EZ) water

Is the single most important molecule to Life!

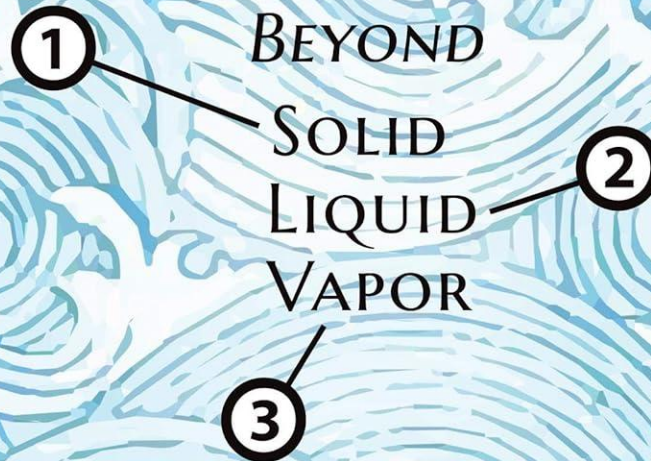
It makes up 2/3rds of the weight of the human body

This equates to 99% of ALL the molecules in the body.

To do its job it has to be in the right form and that right form is variously called 4th phase, gel or exclusion zone (EZ) water. Why?

GERALD H. POLLACK

④ THE
FOURTH PHASE
OF WATER



READ BY KEITH SELTON-WRIGHT

*“The most significant
scientific discovery
of this
century.”*

The fourth phase of water. First the Physics!

It has been assumed that water exists in 3 forms: ice, liquid and gas (steam)

However this does not explain many phenomena such as:

Gelatin desserts which are 99.95% water!

Why ice is so slippery (by contrast with most solids)

How water rises in plants (“transpiration”)

How the “Jesus Christ” lizard can walk on water

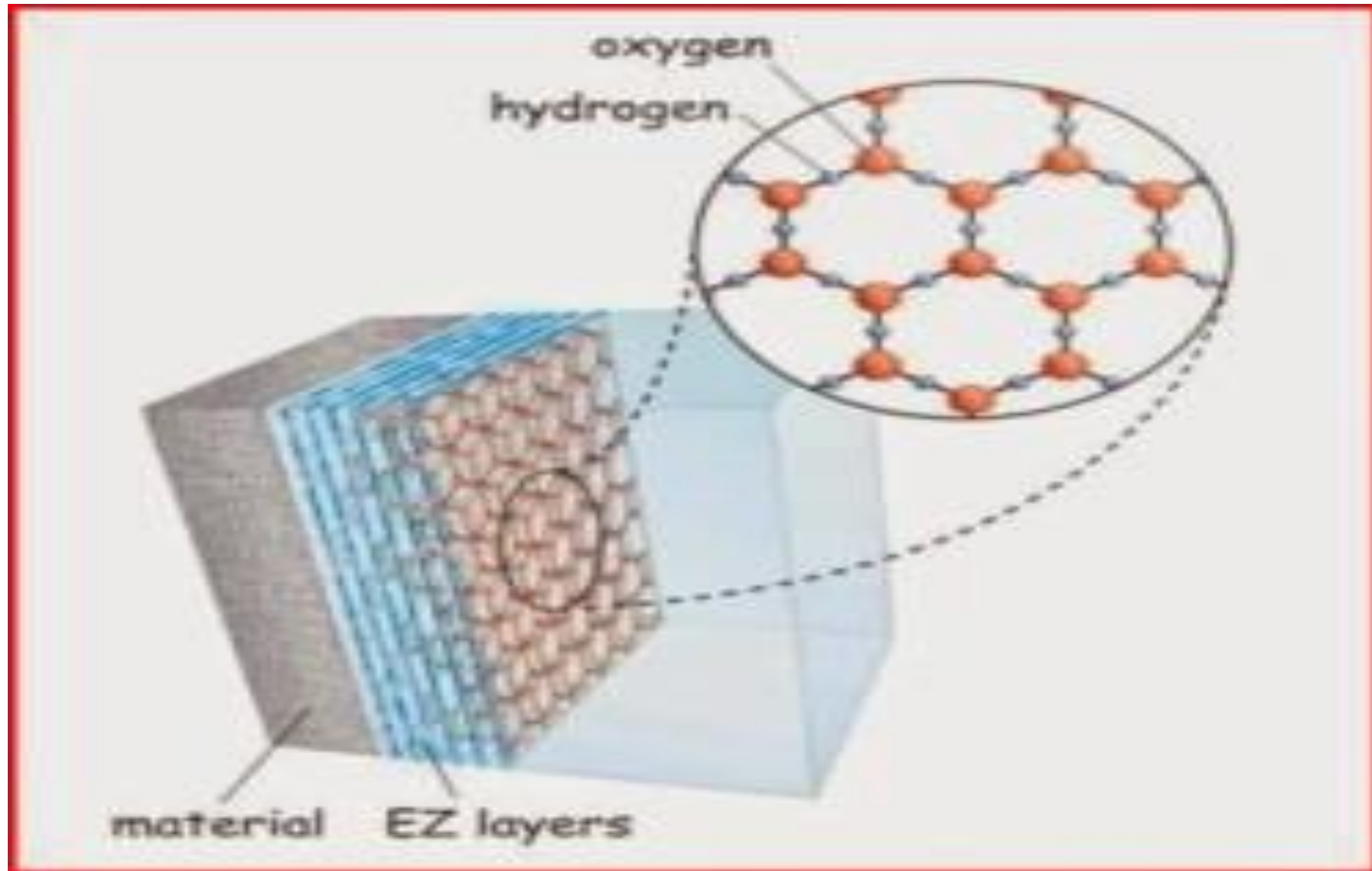
Brownian motion, diffusion, osmosis are not yet fully explained ...

So what is the mechanism?

A molecule of water is made up of one oxygen and two hydrogen atoms BUT the electrons are not fairly distributed. They are pulled towards the oxygen atom. This means the hydrogen atom is slightly positive and the oxygen slightly negative.

So there will be an attraction between water molecules as the slightly positive hydrogen end is attracted to the slightly negative oxygen middle of an adjacent molecule

Things get interesting when water molecules lie against any surface. This may be anything from a glass wall to a cell membrane. If the surface is hydrophilic (ie predominantly negative charges), water molecules line up in a hexagonal structure similar to graphite
(If predominantly positive charges then it forms as a clathrate structure)



This molecular structure is so tight that all other atoms are excluded. Thus it is called exclusion zone water or EZ water. It is also remarkably stable and despite being on an atomic scale, structures extend into the visible range. It can be seen! These EZs take time to form. Below are pictures of such taken over time

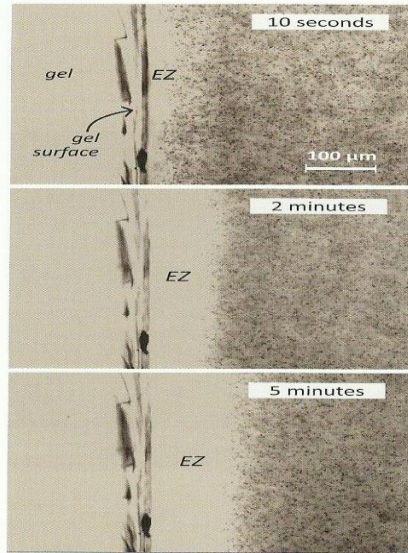


Fig. 3.4 Microsphere-exclusion zone (EZ) next to a gel surface. The zone grows with time and then remains relatively stable after about five minutes.

We started with simpler initial experiments than Hirai. With the same type of gel, we plunked a piece into a chamber and filled it with an aqueous suspension of microspheres. We then looked through a microscope to see what might happen. As soon as the gel surface met the gel, the microspheres began moving away from the surface, leaving a microsphere-free zone just under 100 μm wide. Water remained in that zone, but microspheres did not. When the gel was formed, the zone remained intact: even after several hours of observation, the microspheres resisted invasion. Figure 3.4 shows the development of this microsphere “exclusion zone.”

Our observations revealed that the microsphere-free zone that Hirai did not arise from the hydrodynamics of “blood” flow. The zone had no flow, yet we obtained a similar zone of exclusion about the gel surface appeared to drive the microspheres to retreat — with or without imposed flow. Both scenarios led to the same result: a distinct exclusion zone, or “EZ,” as we call it.

The Conventional Expectation

The exclusion phenomenon seems to fly in the face of modern chemistry. The phenomenon should not exist. It certainly affects the adjacent liquid, but it is widely presumed that the impact does not project into the liquid beyond a few molecular diameters (despite the evidence cited in Henniker’s review article).

Why so limited an impact? The prevailing view denies the theorized presence of an electrical “double layer” of charged surface placed in water will attract oppositely charged ions dissolved in that water (Fig. 3.5, opposite page). Beyond that lies a second layer whose polarity is opposite the first, and so on. Ions diffuse into the liquid. And beyond that double layer must be diffuse charges, etc. Eventually, neutrality prevails. To an extent created beyond those neutralizing layers, the surface should be undetectable — as though the surface were absent.

That minimum distance for insensitivity is labeled “Debye length,” after the Dutch physicist Peter Debye. The value of the Debye length reflects the extensiveness of the counter-ion cloud

EZ zones form against ANY surface – in Nature these are largely hydrophilic surfaces : below you can see EZ zones in polyacrylic acid gel, muscle, gold, Naflon polymer but they also appear in blood vessels and plant roots

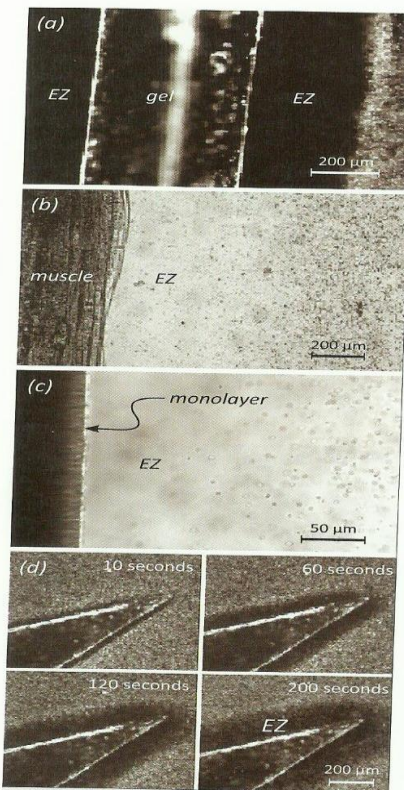


Fig. 3.9 Examples of microsphere-excluding zones, viewed in an optical microscope. (a) polyacrylic acid gel; (b) muscle; (c) a self-assembled monolayer on gold. (d) Nafion polymer, time series.

Although our artifact-seeking experiments consumed a good deal of our energy, they brought an unexpected clue. Those meter-long exclusion zones struck us as implying some kind of crystal-like structure, for crystals easily grow to such lengths: think of an icicle. Crystals also exclude particles as they grow. The prospect that the EZ might be some kind of crystal-like material intrigued us.

Crystals generally grow from nucleation sites, i.e., from surfaces of some kind. It seemed important therefore to determine what kinds of surfaces nucleate exclusion zones.

How General Are Exclusion Zones?

We first examined several gels over and above those mentioned. All water-containing (hydro)gels produced exclusion zones, including gels made of biological molecules and artificial polymers (Fig. 3.9a). We also saw exclusion zones next to natural biological surfaces; they included vascular endothelia (the insides of blood vessels), regions of plant roots, and muscle (Fig. 3.9b). I already mentioned monolayers (Fig. 3.9c). Seeing substantial EZs adjacent to single molecular layers told us that material depth was not consequential: it appeared possible that creating an exclusion zone merely required a molecular template.

Various charged polymers also produced exclusion zones. An especially potent one was Nafion (Fig. 3.9d). Nafion's Teflon-like backbone contains many negatively charged sulfonic acid groups, which make this polymer one of the more potent excluders. Because of Nafion's robust exclusion zones and ease of use, you'll see it mentioned frequently in these pages.

The only exotic features we encountered were breaches — localized surface patches devoid of EZs. Those bare patches were atypical. However, they could be found regularly next to certain metals, and also next to polymeric membranes when straddled by differing solutions, as was the case in our osmosis experiments (see Chapter 11). Those EZ breaches seemed rather like holes penetrating through the ordinary EZ dam.

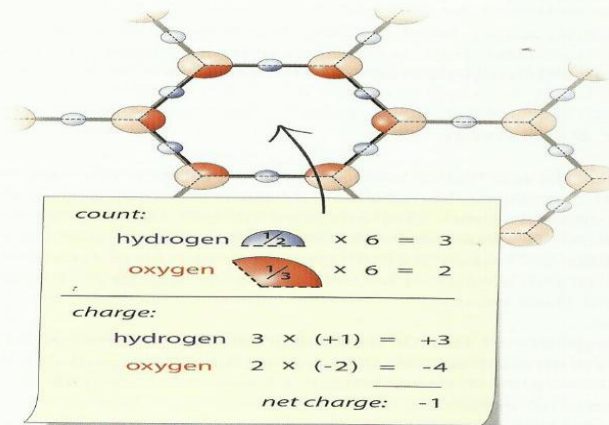
The EZ-nucleating materials described in the paragraphs above fall into the category of "hydrophilic," or water loving. Their love for water

These EZ zones have remarkable properties which explain many biological phenomena
 FIRST they are charged. WHY? The chemical formula of EZ water is different to free water
 Liquid water we have 2 hydrogens to 1 oxygen atom
 EZ water has 3 hydrogens to 2 oxygens – this means that the net charge of each hexagon is minus 1
 The structure of the EZ “honeycomb” is so tight that the proton is excluded.
 This proton binds to a water molecule outside the EZ to form H3O – called hydronium – and of course is positively charged

Second, the authors provocatively state that the substance in question is *not* water. The substance is certainly built of oxygen and hydrogen, but their arrangement in a hexagonal lattice bears little resemblance to their arrangement in the water molecule. This new substance, they asserted, “should not be considered to be or even called water, any more than the properties of the polymer polyethylene can be directly correlated to the properties of the gas ethylene.” The authors considered it clear that this entity was chemically distinct from water.

A third feature, which really made me stand up and take notice, was the ratio of hydrogen atoms to oxygen atoms. As everyone knows, these atoms have a 2:1 ratio in bulk water. In this planar structure, their ratio is 3:2. This feature may not be immediately obvious, but **Figure 4.10** presents a simplified method for verifying the ratio.

Fig. 4.10 Computation of the net charge of each hexagonal unit. To make the count, represent each atom as a sliceable pie; then count all the pie fractions lying within a given hexagon, taking care to remember that the oxygen pie's charge is minus two while the hydrogen's is plus one. The resulting ratio of hydrogen to oxygen is 3:2, and the net charge is of the hexagon is -1.



There are many biologically fascinating aspects of EZ structures
As honeycomb layers continue to stack they form a helical structure.....and this gives us a
framework for the structure of DNA

The planar shift also creates some repulsions: nearby like-charged atoms from respective planes repel one another. However, repulsive forces are fewer than the attractions; and those repulsive forces push away the repelling atoms, thereby weakening the net repulsive force. Indeed, our computations have shown that the attractive forces easily win out.

So the second model yields a stable structure that sticks together naturally. This model yields predictable mechanical behavior: semi-solid when left alone, yet able to flow in response to an imposed shear force. Its behavior should resemble gelatinous egg white.

Variants on that simple stacking theme lead to interesting structural variants. In Figure 4.13b, successive planes of the stack are shifted rightward; but they could just as easily be shifted leftward. With these two options, you could build a left-tilted or right-tilted edifice. These variants could perhaps explain the mirror-image constructs mentioned in Chapter 2.

In fact, the shift direction need not be restricted to left or right alone; planar shift could occur in any one of the six strut directions, leading to endless stacking options. We can even realize helical stacking (Fig. 4.14): Start with a base plane, shift the plane above it in the

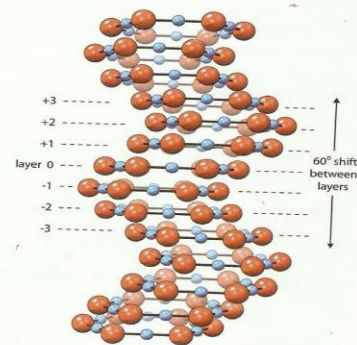


Fig. 4.14 Shifting successive planes by 60° yields a helical structure.

Secondly one of the most primitive molecules in evolutionary biology namely subunit C of ATP synthase – in dry conditions this protein forms an encapsulating shell around water preventing evaporation....it achieves such through the shape being hexagonal and so a tight fit

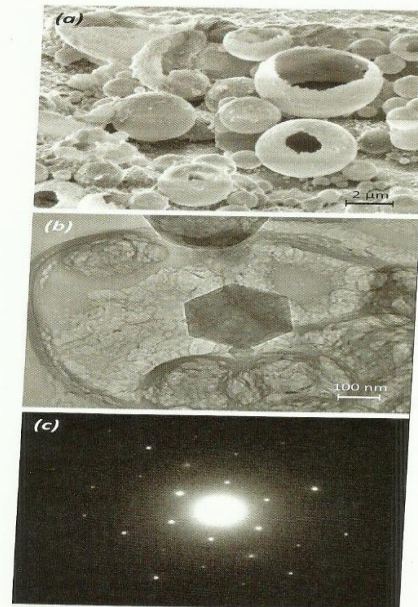


Fig. 4.11 Protein-encapsulated water.¹⁴ Encapsulation produces spheres (a) seen in the scanning electron microscope, and geometric figures (b) seen in the transmission electron microscope. Diffraction pattern (c) obtained from geometric figure shows hexagonal order.

Fig. 4.11 shows two examples of these shelled structures: spherical capsules (panel a) and geometric capsules (panel b). Diffraction patterns obtained from geometric capsules show that the enclosed water is in hexagonal order (panel c). Further, the hexagonal unit spacing, 0.35 nm, is close to that shown in Figure 4.9. Thus, hexagonal order can be seen in substantial volumes of water near surfaces.

Another anticipated feature of these models is the absorption of ultraviolet light. Absorption at or around the 270 nm (UV) wavelength is expected when electrons are “delocalized,” i.e., free to move through the structure. That situation exists most commonly in aromatic ring structures, and also in so-called “crown-ethers,” whose oxygen-containing hexagonal structures are similar to the structure under consideration. Thus, the confirmed EZ absorption at 270 nm (Fig. 3.13) and evidence in support of a hexagonal structure.

So anticipated UV absorption is confirmed, hexamers are experimentally detectable, and two independent sets of considerations lead to essentially the same hexameric model. This supportive evidence provides impetus to consider the model more seriously. Let us press on.

Stacking Honeycomb Sheets

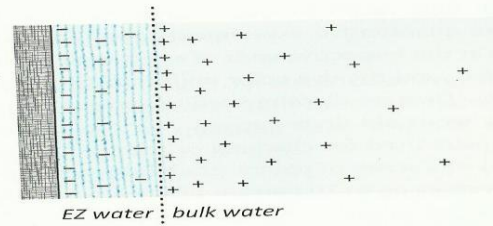
In exploring the proposed model’s explanatory power, we must first determine how the honeycomb sheets stack to form the exclusion zone; after all, the EZ is a three-dimensional entity, not a single sheet. We also need to understand how the initial EZ layer forms. Let us first deal with how the sheets stack.

The simplest stacking model puts the hexagons of all planes in register. You could look down the stack of hexagons and see all the way through.

This in-register arrangement is attractively simple — but impossible. To appreciate why, look back at the top panel of Figure 4.11, which shows an example of planes in register. Suppose you remove the interplanar protons (evident in the bottom panel). That creates the planar stack under consideration. Removing the proton “glue” juxtaposes negatively charged oxygen atoms in one plane with negatively charged

But more interesting is that EZs are electrically charged - -effectively a small battery

Fig. 5.10 Diagrammatic representation of the EZ water battery. Hydrophilic surface at left. The separated charges are deliverable.



they can deliver a significant fraction of that charge. In subsequent chapters, we will see how that charge can provide energy for driving diverse processes, ranging from chemical reactions to hydraulic flows. Indeed, *the EZ battery could be a versatile supplier of much of nature's energy.*

Summary

Aqueous regions next to hydrophilic surfaces contain exclusion zones. Those EZs separate charges. The separated charges constitute a battery (Fig. 5.10).

One pole of the battery is the EZ, typically negative as a result of abundant oxygen atoms. The other pole lies in the bulk-water zone just beyond the EZ; it typically comprises positive hydronium ions, which can disperse freely according to the rules of electrostatics. Drawn towards negativity, many hydronium ions accumulate near the EZ boundary.

While the charge separation mechanism may now seem evident, the maintenance mechanism is not. Like your cell phone battery, the water battery will slowly run down as opposite charges trickle back together. The EZ battery, too, will need recharging. Since nature lacks wall sockets, some other source of energy must be at hand to do the job.

That source had eluded us for several years — until a chance discovery finally set us on the right track. We turn to that next.

.....and this charge can be measured. pH reflects charge

The closer to the EZ, the lower the pH (ie the greater density of protons as hydronium molecules (H₃O⁺))

from the gel, then their accumulation could not exceed
due; after all, no gel can supply an infinite number of pro-
that pre-immersing the gel into a succession of water
to draw out any and all releasable protons made little
subsequent trials, we saw similar drops of pH. It seemed
buildup really did arise as a result of EZ buildup, as we

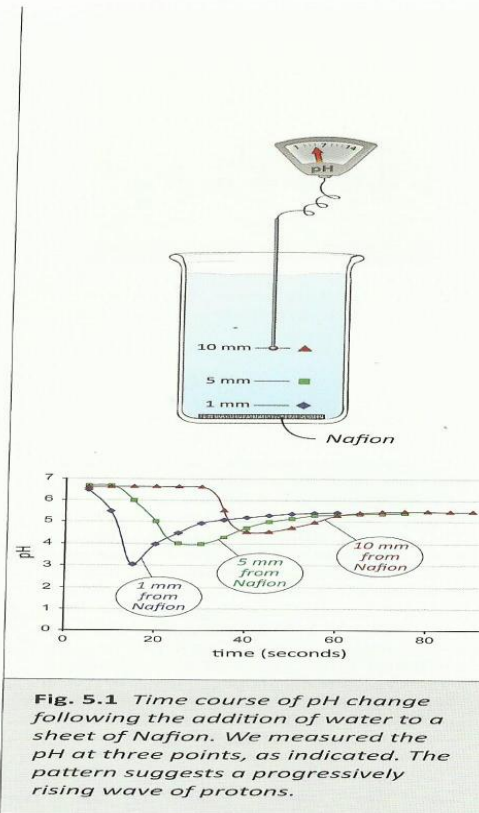
usion was satisfying — like a cool drink on a hot sum-
also reassured us because evidence of high positivity lent
the evidence of the EZ's correspondingly high negativity.
icists, this quasi-stable concentration of negative charge
beyond common experience and therefore difficult to
opposite charges elsewhere reassured us that we were
we track.

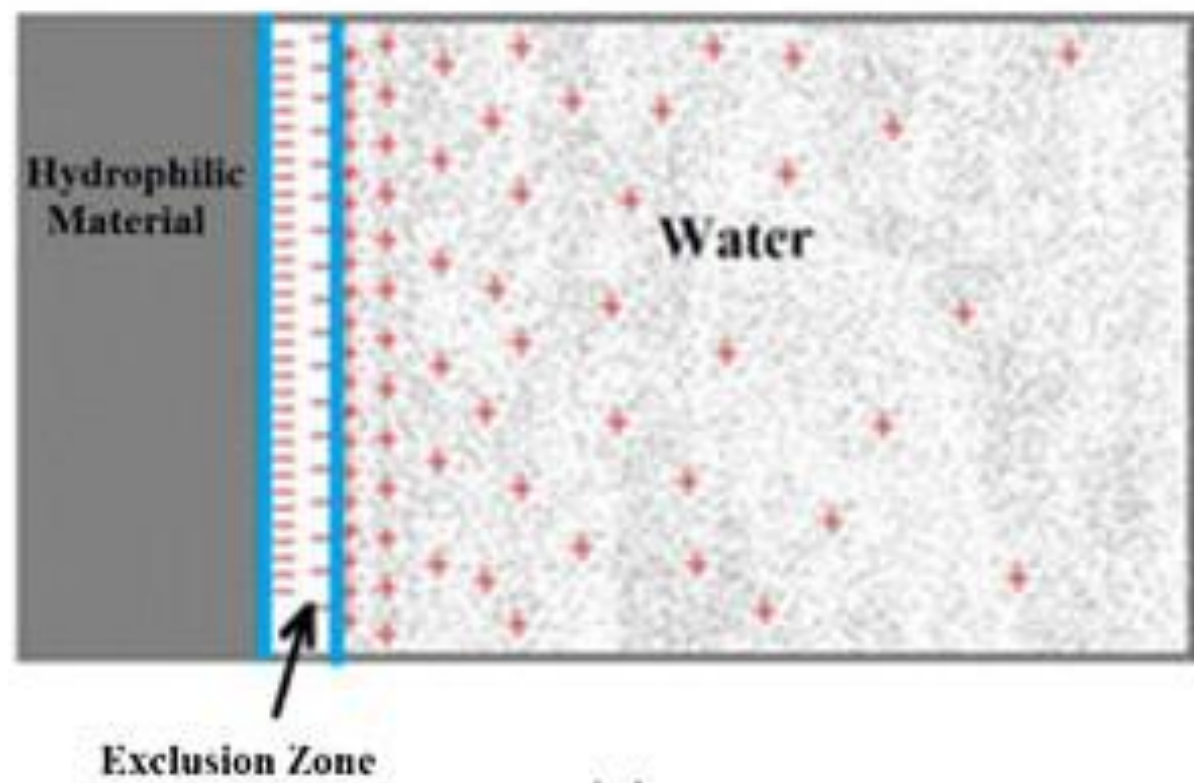
dup

on the dynamics of the proton buildup, we used a min-
be. The probe was small enough that we could track the
ge at a series of distances from the EZ-nucleating sample
l. For the sample, we used a sheet of Nafion secured to
a chamber. We filled the chamber with water and then
proton buildup.

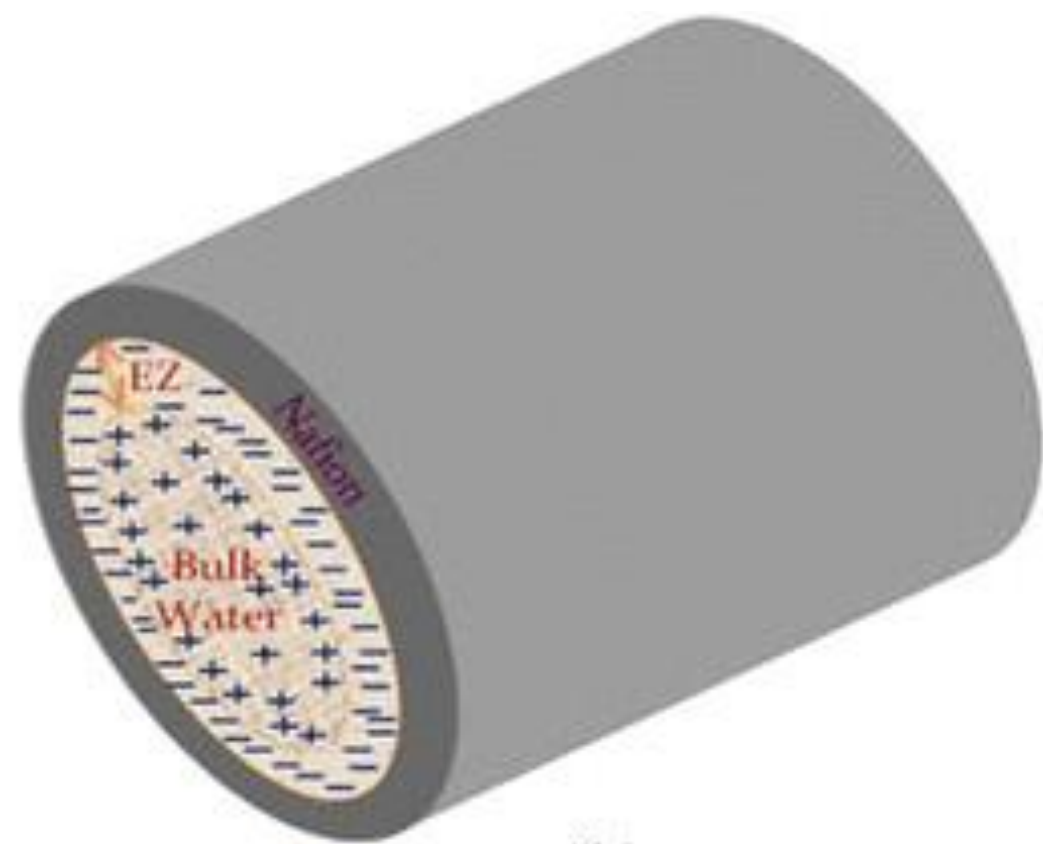
on panel of Figure 5.1 shows records of pH changes
veral distances from the sample. At a distance of 1 mm,
to drop within a few seconds, reaching a low point in 15
en recovering partially as protons spread to more distant
5 mm distance, the pH change started later; at 10 mm,
ater. Eventually, the pH came to roughly the same final
an the initial pH value, at each point of measurement.

shows pH values changing later for measurements
from the Nafion surface. These successive delays
of protons originating from near the sample and dif-
The wave seems likely to originate at the EZ's outer





(a)



(b)

We can start to explain how nerves communicatevia electrical waves across membranes

.....and this may explain how local anaesthetics work since these LAs wipe out EZs in a dose dependent mechanism

(this mechanism was first mooted by Linus Pauling)

Cellular Batteries: Nerves, Pain, and Anesthesia

Duch! The stove is unexpectedly hot. You reflexively withdraw your hand in order to avoid the unpleasant consequences that would otherwise follow.

Nerves mediate that withdrawal: your nerves signal your brain to quickly pull your hand. That signaling mechanism is electrically based: nerve cells bear negative charge, while the regions outside those cells are positively charged. Noxious stimuli trigger a local discharge that propagates along the nerve to your brain. Thus, charge separation is a central feature of nerve-signal transmission; each nerve behaves like a dischargeable battery.

How does this separation of charge occur? According to the prevailing view, the nerve cell membrane contains ion pumps and channels that perform this function, leaving the inside of the cell negative and the outside positive. My last book challenged that view.³

An alternative view suggests that the charge separation arises from water. As we have seen, any water lying next to a charged or hydrophilic surface becomes EZ water; since cells pack charged surfaces so densely inside, most cell water is EZ water. With EZ water predominating, cell negativity could merely reflect EZ negativity.

Beyond explaining cellular negativity, the EZ hypothesis also explains the negativity of gels: gels commonly exhibit large negative potentials similar to those of cells;

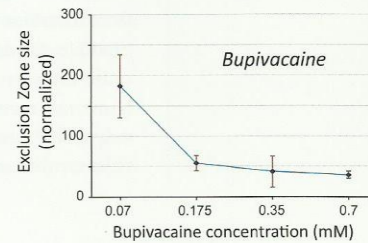
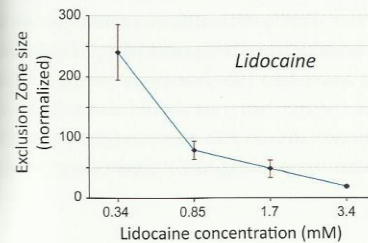


yet they lack any membrane that could pump ions. Thus, in this light, membranes seem almost irrelevant. If EZ water (rather than the putative membrane-based mechanism) powers the electrical activity of the cell, the observation that cells, including nerve cells, can often survive being sliced in half seems less paradoxical.³

If the EZ battery underlies the capacity to transmit signals, then eliminating the battery should eliminate the signals; the brain should never get the message. Local anesthetics do just that: the pain sensation never makes it to your brain. This action provides an experimental testing tool: if the EZ underlies signaling, then anesthetics should wipe out the EZ.

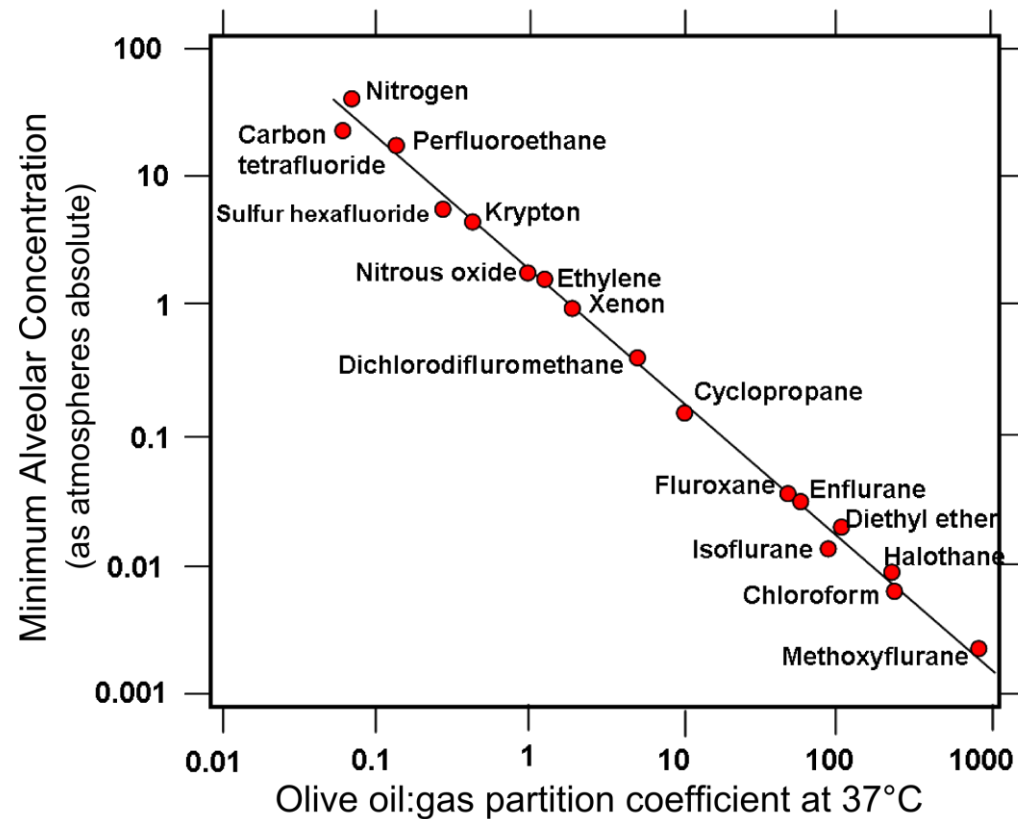
To test this hypothesis, we set up a standard EZ and added a local anesthetic. Clinical concentrations of either lidocaine or bupivacaine reversibly diminished EZ size in a concentration-dependent manner (see figure below). Local anesthetics do indeed wipe out the EZ, as we anticipated. This result might not surprise those who have read the old literature; after all, Linus Pauling, the legendary 20th century chemist, suggested something similar: an intimate link between anesthetic action and water.⁴

Beyond the mechanism of anesthesia, these observations imply something fundamental: an EZ basis for the cell's electrical features. It will be interesting to see whether additional research can confirm that the negative potential of the cell arises from the negative charge of the EZ.



This may also tie in with how general anaesthetics work since their efficacy is directly proportionate to their lipid solubility

The Meyer-Overton correlation for anaesthetics



To get charge separation demands energy- in Life you do not get owt for nowt!

It was a mystery as to where this energy was coming fromuntil a fortuitous experiment

In studying EZs, the microscope lamp was switched offbut when looked at subsequently the EZ had reduced in size.....when switched on it had grown again - the EZ below took several minutes to assemble.....photons were driving the process – energy from light could power the water battery in a similar way to photosynthesis

Ever

What
What
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in the
the lo
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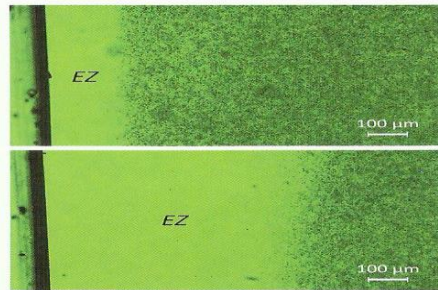


Fig. 6.1 Exclusion zone adjacent to Nafion. Top: control. Bottom: following several minutes of exposure to light.

When he returned the next morning and turned on the microscope lamp to have a look, the exclusion zone had diminished to half its former size. Within a minute or two, the EZ returned to its original size. It was as though the microscope lamp could reinstate the exclusion zone. Something about light seemed to matter (Fig. 6.1).

In retrospect, the role of light should have been obvious. When I raised this energy question during an undergraduate class presentation, a hand shot up and, half questioning, half making a declarative statement, one student blurted out, “Light?” He was spot on. The answer came so easily to that student (whose talents we quickly exploited in our laboratory); but for us, the answer had taken several years to figure out.

By the time of that class, we had managed to ascertain with some certainty that the responsible agent was light. I should be clear: “light” I mean not only the visible part of the electromagnetic spectrum but also the ultraviolet and infrared portions. The water’s energy supply was radiant electromagnetic energy — which the water absorbs and uses for building the EZ and maintaining the electrical charge separation.

Light as Fuel

To account for light’s mysterious expansionary effect, we had considered a potential artifact: a light-induced temperature increase. If incident light could heat the chamber and perhaps mediate the expansion, we quickly concluded that this was unlikely: the EZ’s expansion had begun immediately after the light was switched on — well before the water in the chamber could have heated appreciably. Subsequent experiments confirmed that conclusion: even after the longest exposure that produced substantial expansion, the temperature rose by only a trivial amount.¹ Apparently, the effect of light was not thermal: photons somehow donated their energy toward EZ growth.

That was an exciting moment. It appeared that sunlight could simply provide the energy needed for building order and separating the water environment itself could do the job. Imagine: energy from the sun could power the water battery in much the same way that the sun powers photosynthesis. Wow!

SO which wavelength does this best?

- ALL wavelengths were effective
- Ultraviolet the least effective
- Visible light moderately so
- BEST is Far Infra Red light particularly at 3,000nm
- A combination of time and 3,000 nm produced EZs 5 to 10 times greater (and therefore a bigger battery effect)

There is still much debate as to the mechanism by which Infra Red 3,000nm increases EZs

IR does not have the energy to directly split off a proton from water – but this is a secondary event as the water molecules slowly assemble the honeycomb structure that is electrically stable at H_3O_2^- (one negative charge) leaving a spare hydrogen ion that combines with free water outside the EZ as hydronium ion H_3O^+ (one positive charge)

We then have to ask why the EZ stops growing? The electrical potential near the edge is low and the EZ outer reaches jagged, and the positive charges build up. Hydronium ions are attracted to the spare electron of the EZ and two free water molecules result
 Creation and destruction balance
 Energy driven EZ production balance neutral EZ erosion

● -



Fig. 6.10 Jagged outer reaches of the exclusion zone. Hydronium ions penetrate the valleys between the mountain peaks because of attraction to negative charges.

in that accidental overnight experiment: the EZ narrowed because a major energetic input was switched off; when that input was restored the next morning, the EZ grew back to its former size.

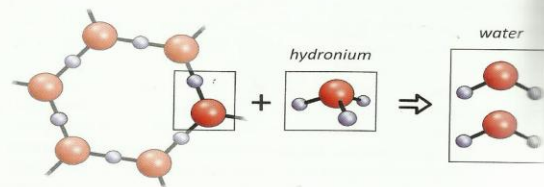
To understand what governs EZ size, then, we need to consider the balance between energy-dependent growth and the natural tendency to decay. When those two processes balance, the EZ attains a steady size. Growth was just explored, and growth-limiting factors such as surface roughness and degree of hydrophilicity were dealt with earlier. On the other hand, we've barely touched on the process of decay: how exactly does the EZ erode?

In order to answer that question, we need to consider the outer reaches of the exclusion zone, where you might expect attrition to take place. There, the electrical potential measures closer to zero, which likely means that some cleaved protons remain embedded in the lattice and/or the lattice is relatively more open (Chapter 4); see Figure 6.10.

A loose lattice implies easy molecular penetration. The most likely candidates for penetration are hydronium ions, for their positive charges are ineluctably drawn toward the high negativity of the EZ's inner reaches. So, hydronium ions invade the valleys between the EZ peaks.

This invasion has consequences. Having penetrated, these positive ions will be quickly captured by flanking negatively charged EZ molecules. The result is the merger that I alluded to earlier: an H_3O^+ combining with a lattice-structural unit (OH $^-$), which yields two water molecules (Fig. 6.11). This erosive action loosens the EZ's hexameric structure.

Fig. 6.11 Natural erosion of exclusion zone. Combining a hydronium ion with one EZ structural unit extracts that unit from the lattice, resulting in two water molecules.



No system is perfect. If there is a mismatch (eg some electron hungry process draws electrons away) then there is production of Reactive Oxygen Species (ROS) such as superoxides such as 2 oxygens with a single negative charge or $H_2 O_2$

- In order to mop up these free radicals, every cell in the body, indeed every cellular compartment, has super-oxide dismutases.
- Those within mitochondrial are Mn SODs, intracellular and extracellular are Zn, Cu SODs (ergo zinc, manganese and copper are essential for Life)
- It has long been an enigma why these enzymes are so ubiquitous – the answer is that wherever you have surfaces, water and light you will be generating free radicals.

So we have water that can accept light energy from the sun and convert this into electrical energy which the cell can employ to drive reactions (such as enzyme reactions) within the cell.
When this was further explored reaction times varied markedly but why so?

Constancy could only be achieved by use of a Faraday cage ie there was an environmental factor from outside which impacted

Experiments WITHOUT a Faraday cage showed.....

December to January – reactions were slow

Increased through March

Peaked June July...then declined

Increased with sunspots and solar flares

Changed with a moon eclipse

Perhaps this is a mechanism that explains how astronomical phenomena impact on our health?

What about over the 24 hours? Voeikov measured light emitted from aqueous solutions. These were in a light tight (dark), temp controlled chamber.
 He concluded that cosmic energy impacted and had profound effect up to 72 hours after the eclipse

More Oscillations

Further evidence for radiant energy absorption in water comes from Vladimir Voeikov, whom I mentioned earlier. Voeikov studies the light emitted from aqueous solutions. The intensity of that emitted light oscillates with the daily cycle (Fig. 7.3a). The experiment illustrated in the figure took place in a light-tight chamber with a controlled temperature; hence, the oscillation exceeds any plausible variation arising from external temperature fluctuation. The emitted light oscillation was evidently the effect of some kind of radiant input beyond visible light, which had been blocked. The radiant energy evidently varied with the diurnal cycle. This implies an influence of solar energy.

Another such recording revealed more. In Figure 7.3b, note the sharp upward inflection near the beginning of the curve. Suspecting some experimental fluke, Voeikov checked and found that the upturn coincided exactly with the onset of a local lunar eclipse; this suggested that cosmic energy could impact the light output. That cosmic impact was evidently strong enough to overshadow the daily oscillation.

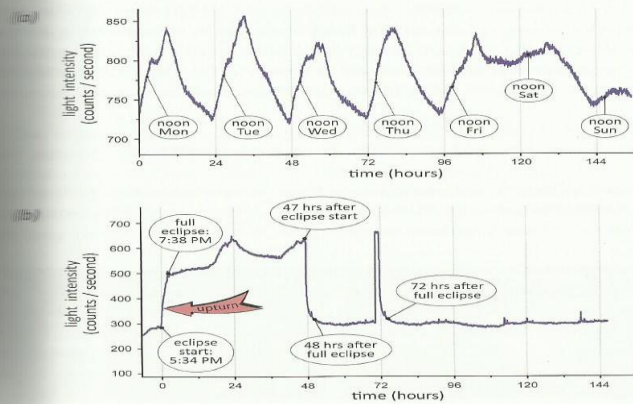


Fig. 7.3 (a) Light emission recorded from water containing bicarbonate ions and enhanced by dissolved lumol. Note the periodic intensity variation. (b) Similar to (a) but recorded during an eclipse of the moon.

Light striking water within cells produces energy in many ways

Optical energy (as detailed by Voeikov) (and this can persist for over a year after dark storage)

Physico-chemical work – ie charge separation

Electrical work – microelectrodes – one within the EZ and one in bulk water will drive an electrical current between the two

Mechanical work – one Q I always asked myself is why does blood flow through capillaries? When you consider there is no pressure gradient AND red cell diameter is greater than capillary diameter (they have to twist and distort to get through).....so how on earth?

A small bore tube in water....after a while the water flows from one end to another....why?



Fig. 7.8 Water clock. The underlying principles differ from those that electrochemists might surmise (see Chapter 12).

substantial energy — practically as much as the electrical energy used to build those charged zones.

Thus, water can deliver electrical energy. Imagine using water to run your cell phone! That prospect should not come as a complete surprise, for water-based batteries can already produce enough electrical energy to power a clock (Fig. 7.8).

(iv) Mechanical Work

In the context of mechanical work, I refer to water movement, or flow. Producing flow requires energy input: if you transport water uphill, you expend energy; you might even develop a sweat. Even if you drive the water through a horizontal tube, you still need to expend energy in order to overcome molecular friction or viscosity. Driving flow of any kind requires energy input.

Now, suppose neither you nor some other supplier of energy is on hand to drive the flow. Then the energy must come from the water itself. That's what I would like to illustrate next: flow production in the absence of an obvious driver — other than the subtle energy stored in the water. I present three examples.

(a) **Tubes.** The most dramatic example is the flow through hydrophilic tubes (Figure 7.9). To see this, drop a 1-mm length of Nafion tubing into a small chamber of water, taking care to ensure that the water fully permeates the inside of the tube. Then make sure the tube lies flat at the bottom of the chamber. To track any flow, add some microspheres or a blob of dye.

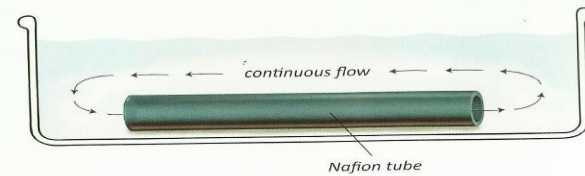


Fig. 7.9 Practically incessant flow occurs through hydrophilic tubes immersed in water.