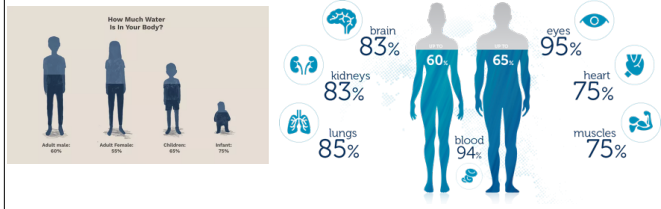
ANBI 141 Evolution of the Human Diet

Lecture 10: Minerals and Water

Pascal Gagneux October 25, 2022

Water in the human body



Practice Question: How much water does the human body of an adult contain?
Answer: ~60%.

Minerals

Minerals play important roles in maintaining blood pressure, fluid & electrolyte balance, and bone health; making new cells; delivering oxygen to cells; and contributing to normal muscle and nerve functioning. Minerals are widely distributed in foods, with specific minerals being found in certain foods. By eating a variety of nutrient-dense foods from the 5 food groups, you will have a mineral-rich diet.

Practice Question: What roles do minerals play in the body?
Answer: blood pressure, electrolyte balance, bone health, gas transport, muscle and nerve function.

Open, drier habitat

Reuse of scarce water sources shared with other animals:
Novel opportunities for disease transmission

The unique ecology of modern humans, the exploitation of much drier and variable habitats created many novel opportunities for disease. Our ancestors had to solve many new problems: finding safe and expendable water sources.

Exploiting of coastal resources, marine and fresh water

New opportunities for infection by water borne parasites

Olduvai, now and 2 million years ago

Reconstruction of Olduvai Gorge, 2 million years ago. Hominins used the rich resources near the water, but also paid steep prices in terms of predation by crocodiles.

Water holes are dangerous

At a bend along Kruger National Park's Sweni River, a Nile crocodile (*Crocodylus niloticus*) lies in wait, hidden beneath the placid surface of the shallower-than-usual water. It's the spring of 2016, and the park's herbivores are suffering through the worst drought since official record-keeping began in 1904. Kruger's predators aren't having any trouble finding food, however. Emaciated, easy-to-catch prey abound, and the haggard animals are forced to congregate around the park's few remaining watering holes. It's with these circumstances in mind that photographer John Mullineux has trained his camera on the river bend, waiting with anticipation as a group of impala (*Aepyceros melampus*) approach to drink.

Water holes are dangerous

Large land predators also use water holes and are aware of the many opportunities for hunting there.

Practice Question: What are the advantages and disadvantages of drinking from water holes?

Answer: predictable source of water, risk of disease or predator attack.

"Savanna" adaptations

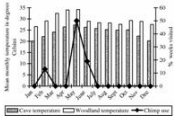
Semliki, Uganda

McGrew et al. 2007

Fongoli, Senegal

Pruetz et al. 2015

Photo: Maja Gaspersic



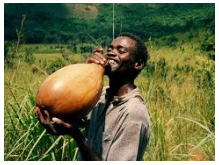
Pruetz 2007

Chimpanzees digging for water in Uganda (Semliki Forest). Chimpanzees cooling down in water and caves (not bad for a species called *Pan troglodytes*).

Transporting water?

technical solution to get water on demand…..

Ostrich eggs and bottle gourds



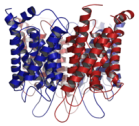
Bottlegourds are among the earliest domesticated plants in Africa. The plants floated across the Atlantic where it established and patiently "waited" a second domestication by humans who arrive there in the last 15 thousand years only!

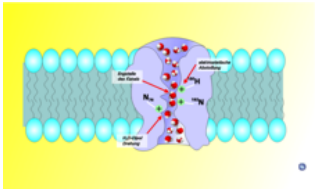
Practice Question: What were the earliest containers used for water transport?

Ostrich eggs and bottle gourds.

Transporting water into cells

Peter Agre and aquaporins



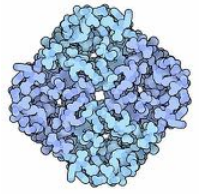


Narrow protein channels through the lipid membrane!

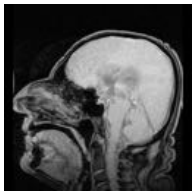
Peter Agre was awarded the Nobel price for his discovery of water channels: Aquaporins. He is one of the 150 signatories to the letter about GMOs to Greenpeace….

Practice Question: How can water molecules get into a cell?
Not on their own, they need channels: aquaporins.

Transporting water into cells



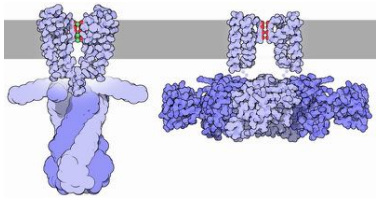
David Goodsell, TSRI



Aquaporin 4 protein in the choroid plexus transportng water into the CSF

Different aquaporin molecules (there are 4 different genes in the human genome) regulate the flow of water in and out of cells in different parts of the body including the kidneys and the brain.

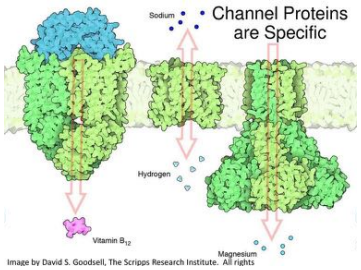
Transporting ions across cell membranes



Potassium channel

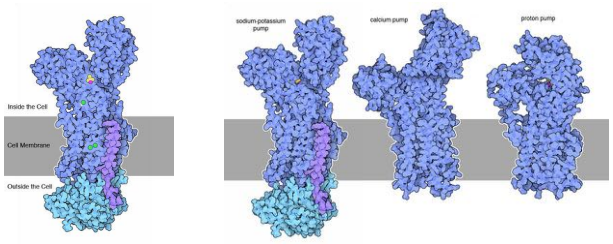
Practice Question: How can charged ions get across cell membranes?
They need to go through channels and pumps.

Specific channel proteins



Our genomes include over 200 different genes for ion channel proteins, many more for vitamins, amino acids etc..

Active Transport: Molecular pumps!



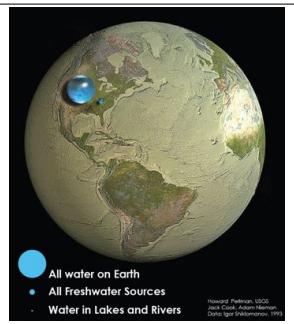
Sodium Potassium Pump

Sodium-Potassium Pump. Cells continually pump sodium ions out and potassium ions in, powered by ATP. Sodium-potassium pump with potassium ions (green) in the transport sites and a phosphate analogue (yellow) in the ATP-binding site. The cell membrane is shown schematically in gray. Our bodies use a lot of energy. ATP (adenosine triphosphate) is one of the major currencies of energy in our cells; it is continually used and rebuilt throughout the day. Amazingly, if you add up the amount of ATP that is built each day, it would roughly equal the weight of your entire body. This ATP is spent in many ways: to power muscles, to make sure that enzymes perform the proper reactions, to heat your body. The lion's share, however, goes to the protein pictured here: roughly a third of the ATP made by our cells is spent to power the sodium-potassium pump.

Pumping Ions. The sodium-potassium pump (PDB entries 2zxe and 3b8e) is found in our cellular membranes, where it is in charge of generating a gradient of ions. It continually pumps sodium ions out of the cell and potassium ions into the cell, powered by ATP. For each ATP that is broken down, it moves 3 sodium ions out and 2 potassium ions in. As the cell is depleted of sodium, this creates an electrical gradient and a concentration gradient, both of which are put to use for many tasks.

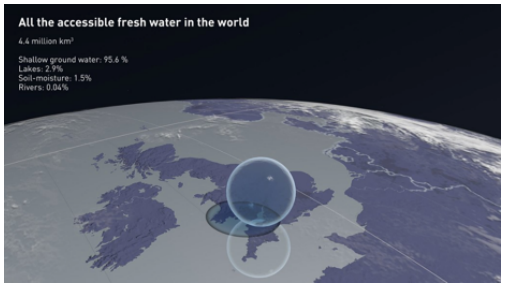
Amazing Gradients. The most spectacular use of this gradient is in the transmission of nerve signals. Our nerve axons deplete themselves of sodium ions, then use special voltage-gated sodium channels to allow the ions to rush back in during a nerve impulse. The sodium-potassium pump has the job of keeping the axon ready for the next signal. The gradient is also helps control the osmotic pressure inside cells, and powers a variety of other pumps that link the flow of sodium ions with the transport of other molecules, such as calcium ions or glucose.

Global Water

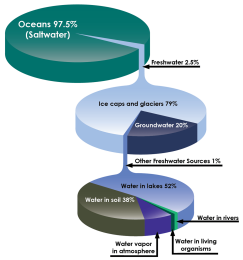


A mere bubble is all we have……and most of it is very salty.

Only a tiny fraction is drinkable water



Trickle trickle….



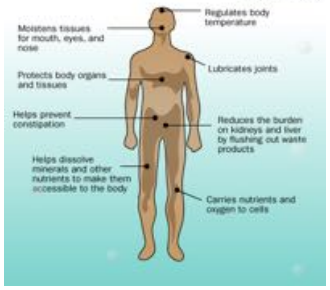
Practice Question: Is there more water in the world's rivers or in all living organisms?
Answer: About the same amount in each.

Lake Tanganyika : 16% of the worlds fresh water

1,471m deep, almost 5000 feet.

Snorkling in Lake Tanganyika

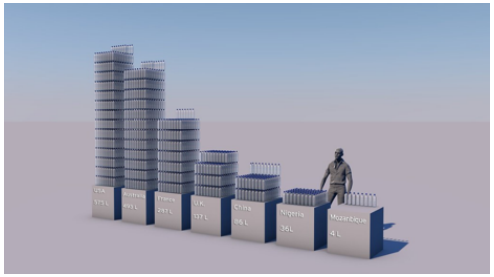
What water does for you:



Our bodies are about 60 percent water. Water regulates our body temperature, moves nutrients through our cells, keeps our mucous membranes moist and flushes waste from our bodies. Our lungs are 90 percent water, our brains are 70 percent water and our blood is more than 80 percent water. We cannot function without water. Most people sweat out about two cups of water per day (0.5 liters). Each day, we also lose a little more than a cup of water (237 ml) when we exhale it, and we eliminate about six cups (1.4 l) of it. We also lose electrolytes -- minerals like sodium and potassium that regulate the body's fluids. So how do we replace it? We can get about 20 percent of the water we need through the food we eat. Although the amount of water that we need each day varies, it's usually about eight cups (2 l). But instead of worrying about getting in those eight cups, you should just drink when you start to feel thirsty.

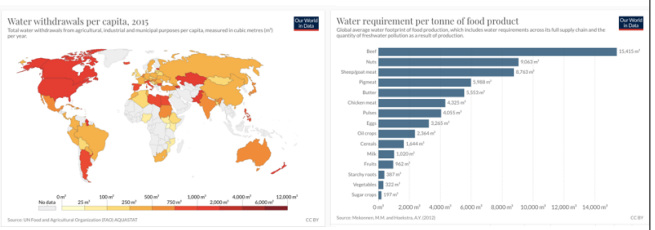
Sweet potato gnocchi purple and orange…

We are “water hogs” in the USA!



Giant disparities in how much water is used across regions and countries.

Comparative water use

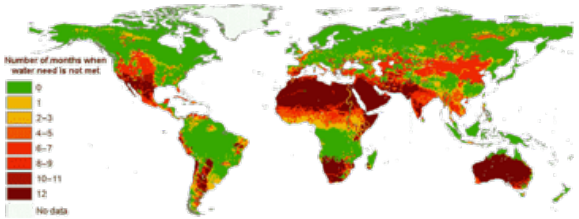


Beef and nut rich diets require tons of water!

Practice Question: Which food requires more water for its production, nuts or beans?

Answer: Nuts.

Water scarcity globally:



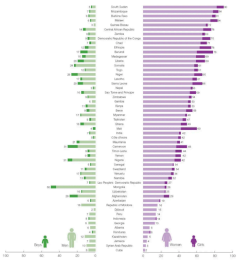
More than half the world's population is affected by water scarcity

M. M. Mekonnen and A. Y. Hoekstra, Four billion people facing severe water scarcity, ***Science Advances*****,** 2 (2016)

Practice Question: What fraction of the world population faces severe water scarcity?

More than half.

Getting Water



Who has primary responsibility for collecting water in rural areas? This graph details where the burden falls, by gender and age, in countries where at least one in 10 households have water off-premises. Photograph: WHO/Unicef Joint Monitoring Programme

Practice Question: What is the connection between water and gender?

Answer: Women around the world carry most of the water where there is no tap water.

Getting Water

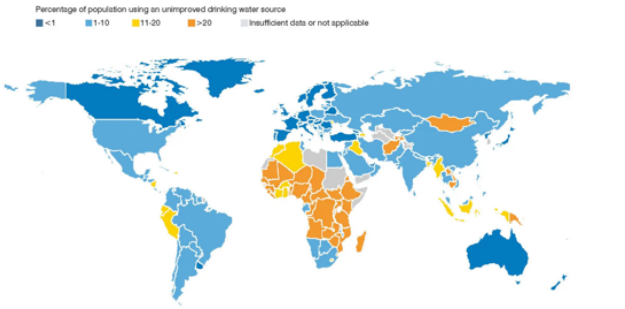
India

Mali

Paraguay

Women carry most of the water in Gujarat India, Mali Africa and Paraguay, South America.

Water safety:

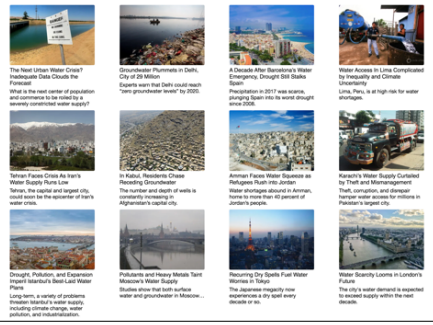


Water can be unsafe for many reasons: infectious agents (Hepatitis A, Rotavirus, Norovirus, Cholera, Shigella, Amoeba, Salmonella etc) and pollution (natural toxic minerals Arsenic, industrial lead, mercury, organic toxins from petrochemical industry).

https://www.circleofblue.org/

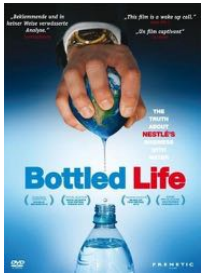
check out this NGO (non governmental organization)!

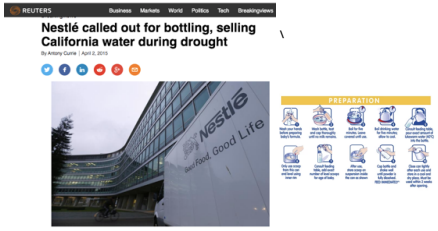
Global Water Issues



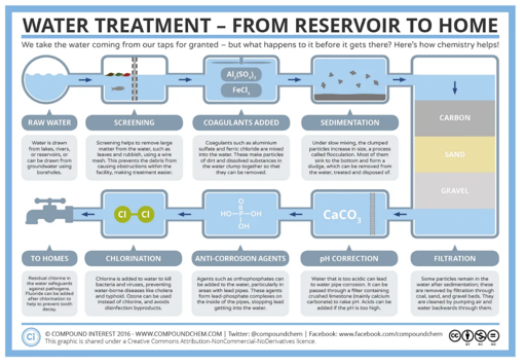
Some of the current water issues globally.

Nestle and water





The water business is incredibly lucrative. How ethical is it?



Water treatment is a huge achievement for public health. Abolishing tap water chlorination can come at huge costs: Cholera (El Tor strain) epidemic in Lima Peru in the 1990s.

Practice Question: Why is chlorine added to tap water??

Answer: For disinfection.

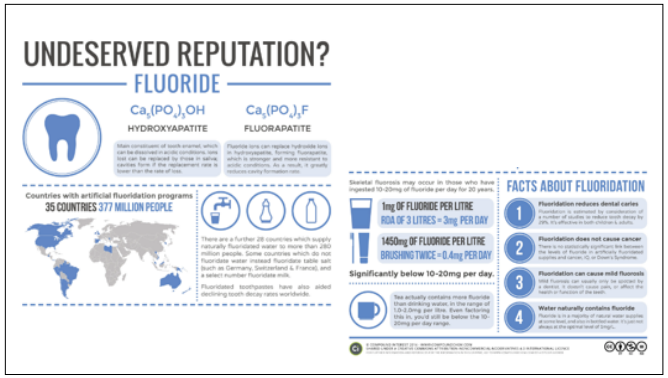
Fluorine

fluoride, the anionic form of the element is both toxic and essential.

vapor

fluorite GaF2 and cryolite Na3AlF3

The element fluorine is a greenish yellow gas. This a simulant, showing how fluorine appears (though the actual gas would be less intensely colored in small volumes). The real element would corrode even borosilicate glass.



Fears about too much fluoride?

Practice Question: Why is fluoride added to drinking water?

Answer: For dental health (enamel strengthening).

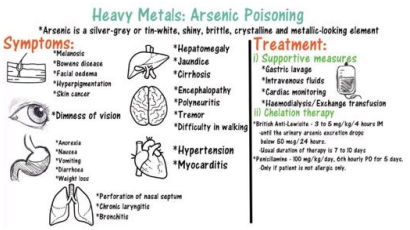
Excess fluoride in water

Hadza men (Laui left and Muapo right) with excess fluoride damage on their teeth.

Practice Question: What are the effects of excess fluoride?

Answer: Negative impact on teeth.

Arsenic in ground water

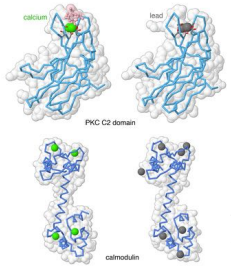


Arsenic is one of the 10 chemicals classified as a public health concern by the World Health Organization; it slowly poisons the body, potentially causing skin lesions, damage to the peripheral nerves, gastrointestinal ailments, diabetes, renal (kidney) failure, cardiovascular disease, and cancer. At least half the people who were known to be at risk of arsenic contamination live in the Ganga-Brahmaputra basins of Bangladesh and India.

Practice Question: Is arsenic in drinking water from industrial pollution?

Answer: No, mostly from natural arsenic rich rocks.

Lead in water



Treating with orthophosphate can promote the formation of lead phosphate coating, preventing lead leaching into the water.

Lead poisoning from tap water and other sources is a very serious concern!
In Flint Michigan, insufficient treatment of tap water led to lead leaching from metal pipes!
Practice Question: How can water treatment prevent lead leaching from metal pipes?
Answer: Treating with orthophosphate can promote the formation of lead phosphate coating, preventing lead leaching into the water.

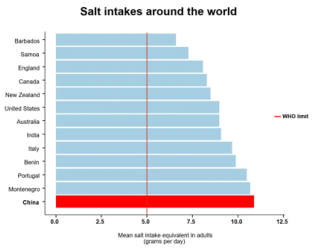
Salt





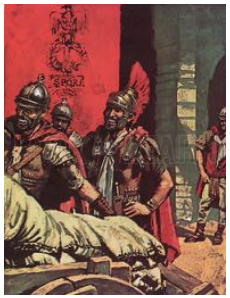

NaCl each component of our beloved salt is very nasty on its own!

Salt Planet



High sodium consumption (>2 grams/day, equivalent to 5 g salt/day) and insufficient potassium intake (less than 3.5 grams/day) contribute to high blood pressure and increase the risk of heart disease and stroke. The main source of sodium in our diet is salt, although it can come from sodium glutamate, used as a condiment in many parts of the world. Most people consume too much salt—on average 9–12 grams per day, or around twice the recommended maximum level of intake. Salt intake of less than 5 grams per day for adults helps to reduce blood pressure and risk of cardiovascular disease, stroke and coronary heart attack. The principal benefit of lowering salt intake is a corresponding reduction in high blood pressure. WHO Member States have agreed to reduce the global population's intake of salt by a relative 30% by 2025. Reducing salt intake has been identified as one of the most cost-effective measures countries can take to improve population health outcomes. Key salt reduction measures will generate an extra year of healthy life for a cost that falls below the average annual income or gross domestic product per person. An estimated 2.5 million deaths could be prevented each year if global salt consumption were reduced to the recommended level.

Salarium



Roman soldiers were paid in salt: the salarium came to mean “salary”

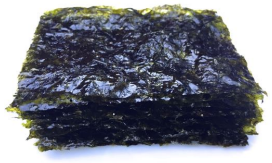
Practice Question: what is the origin of the word salary?

Answer: Roman soldiers paid in salt.

Nori (海苔), Gim (김), zicai 紫菜

Pyropia (Porphyra) yezoensis and P. tenera.

good source of iodine and vitamins B12!!



sulfated galactan (polygalactose)

Bacteroides plebeius six strains of *B.plebeius* had been discovered, and all of them came from the bowels of Japanese people. The seagoing bacterium called *Zobellia galactanivorans* found on nori (red seaweed) donated one of its genes to *B plebeius*, which gained the capacity to digest polygalactose (galactan). Chemical structure of the common repeating units of sulfated galactans in red seaweeds.

Green and blue arrows show α-1,4 and β-1,3 linkages, respectively. D-Gal, D-galactose; D/L-Gal, D-galactose or L-galactose.

Practice Question: Which plant food is a good source of iodine and vitamin B12?

Answer: Nori sea weed.

Trans-Sahara Salt Transport

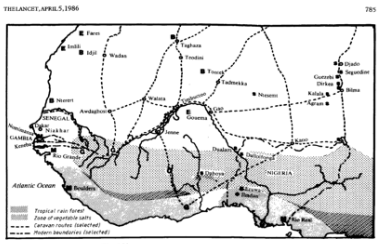
Century old salt transport in the Sahara. Salt tablets in the market in Timbuktu, boat transport on the Niger River.

Trans-Sahara Salt Transport

https://www.youtube.com/watch?time_continue=15&v=Bi9bJhRZtKA

Trans-Sahara Salt Transport

Different Ways to Salt!



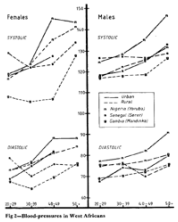


Fig 3—Blood-pressures in West Africans

Wilson, T 1984 ***The Lancet***

Populations with longer exposure to high salt (Gambia and Senegal) have lower blood pressure!

Different West African population react differently to salt. Population with longer exposure to high salt (Gambia and Senegal) have lower blood pressure!

Mismatch

Most palaeoanthropologists (Klein, 1999), human geneticists (Neel, 1994) and evolutionary theorists (Gould, 1980) concur that the average individual living now is almost identical, genetically, to his/her ancestors of 50 kya.

The lifestyle of ancestral humans, that for which the contemporary genome was originally selected, could be considered a candidate paradigm. Deviation from the essentials of that experience appears to underlie the pathophysiology of chronic disease propagation and, conversely, behaviour that tends to match the Stone Age lifestyle model seems to forestall development of chronic illness while positively enhancing health.

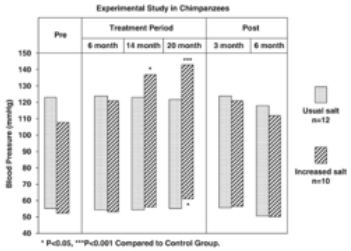
There have been genetic adaptations in the last 10 thousand years: lactase persistence, desaturate in Inuits, salivary amylase in grain eating people, PDE10 gene in Bajau sea nomad for marine hunting etc…..

Overall the idea that our biology might be mismatched with the calorie rich and sedentary lives most of us lead seems valid.

Practice Question: What is the concept of mismatch in evolutionary medicine?

Answer: Our biology is mismatched with our modern way of life.

High salt diet increases blood pressure in chimps



Denton *et al.*1995 ***Nature Medicine***

Blood pressure in chimpanzees who either continued on their usual diet (0.5g/day of salt) or were given an increased salt intake (10-15g/day). At the end of the 20-month study, the salt supplements were stopped and blood pressure declined to that of the control group. Adapted from Denton et al. ***Nature Medicine*** 1995

Salt and cardiovascular mortality

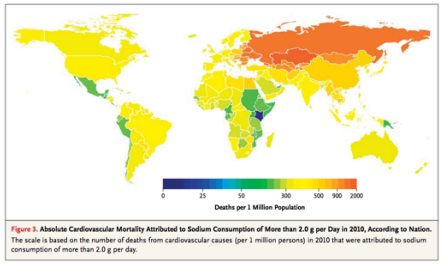
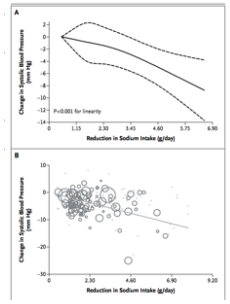


Figure 3. Absolute Cardiovascular Mortality Attributed to Sodium Consumption of More than 2.0 g per Day in 2010, According to Nation.
The scale is based on the number of deaths from cardiovascular causes (per 1 million persons) in 2010 that were attributed to sodium consumption of more than 2.0 g per day.

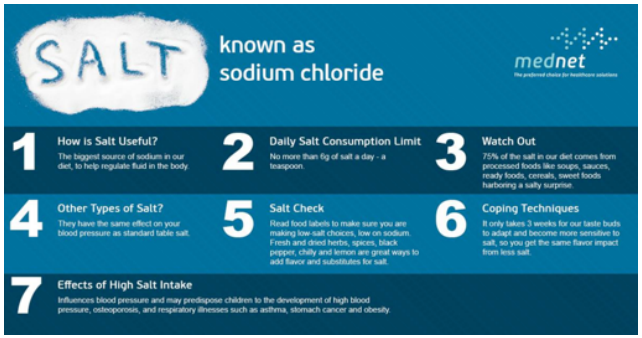
Mozafarrian, D *et al. 2014* ***NEJM***

Salt intake and blood pressure!



Mozafarrian, D *et al. 2014* ***NEJM***

Effects of Reduced Sodium Intake on Systolic Blood Pressure. Data are from 103 trials and include 107 comparison interventions (6970 persons). Reductions in sodium intake ranged from 0.53 to 6.56 g (23 to 285 mmol) per day (mean±SD, 2.28±1.27), the duration of the intervention ranged from 7 to 1100 days (mean±SD, 65±160), and the age of the participants ranged from 13 to 73 years (mean±SD, 47.4±14.4).
As shown in Panel A, the effect of reduced sodium intake on systolic blood pressure was linear (P<0.001 for linearity), and there was little evidence of nonlinearity (P=0.58 for nonlinearity). The solid line represents the central estimate, and the dotted lines the 95% confidence intervals [CIs]. The model is based on inverse-variance–weighted, restricted-cubic-spline regression adjusted for age, race, and the presence or absence of hypertension.
As shown in Panel B, this relationship was further examined with the use of inverse-variance–weighted linear meta-regression. Each circle represents one randomized comparison of the intervention with the control group in each trial, and the size of the circle corresponds to its inverse variance weight. The fitted line represents the effect of reduced sodium intake across all trials (i.e., the effect according to the meta-analysis). Each reduction in sodium intake of 2.30 g (100 mmol) per day was associated with a reduction of 3.82 mm Hg (95% CI, 3.08 to 4.55) in systolic blood pressure.



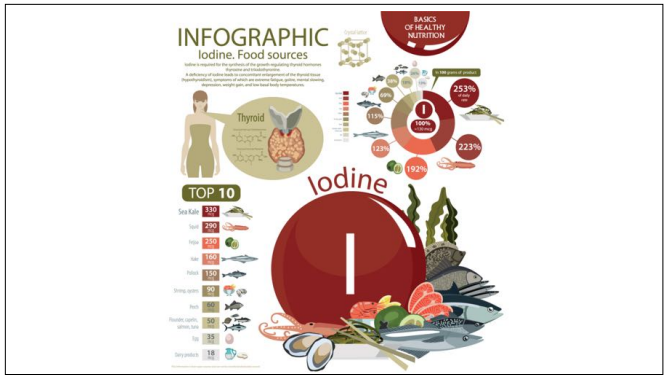
Iodine

Bonobos in the congo basin eat water lilies for iodine

solid iodine

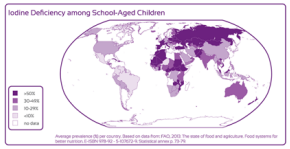
vapor

Practice Question: How do bonobos in the iodine poor Congo basin find iodine?
Answer: By eating water-lilies.



Practice Question: Why is iodine so important for health?
Answer: Our bodies require iodine to make thyroid hormone.

Iodine Deficiency



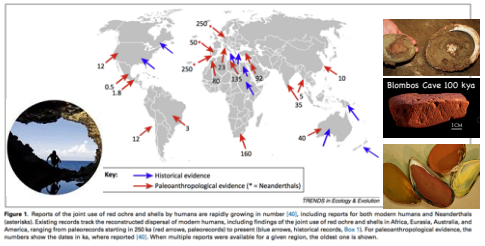
Practice Question: What is a goiter?
Answer: Enlarged thyroid gland due to lack of iodine.

Iron

decimal point error in old German research paper?

So is spinach a good source of iron? Yes and no. A cup of cooked spinach contains about 6.5 mgs of iron, which is a fair amount, considering that an average person needs about eight milligrams a day. Premenstrual and pregnant women need 18 and 27 mgs, respectively. A cup of raw spinach has less than 1 mg because of the high water content. But there's another issue: Spinach is high in oxalic acid, which inhibits iron absorption. Basically, spinach is not a great source of iron. And as far as iron providing extra energy goes, that would only be the case if weakness were due to iron-deficiency anemia. Popeye, being a sailor, is unlikely to have suffered from such a deficiency given that seafood is an excellent source of "heme" iron, the most readily absorbed form.

Red ochre and shells



Duarte ***TREE*** 2014

Ochre (iron oxide rich rock) and shellfish co-occur in many ancient human sites. Why?
Could the rich source of lipids in shellfish and the iron in the ochre both have had a dietary role?

Red ochre and grease

Himba Woman (Namibia) Hamer Woman (Omo Valley Ethiopia)

Himba Woman (Namibia) and Hamer Woman (Omo Valley Ethiopia).
ochre mixed with grease is applied to body and hair. Both ancient and modern peoples use ochre to decorate themselves and their environments as well as in sunscreen and other functional applications

Dietary sources

Calcium: milk products, smaller amounts in tofu, greens and legumes

Iron: meat, poultry, fish, eggs, legumes, greens and dried fruits.

Phosphorous: milk and milk products and meat and alternatives, such as beans, lentils and nuts. Grains, especially whole

Potassium: Bananas, oranges, cantaloupe, honeydew, apricots, grapefruit (some dried fruits, such as prunes, raisins, and dates, are also high in potassium) Cooked spinach. Cooked broccoli. Potatoes. Sweet potatoes. Mushrooms. Peas. Cucumbers.

Sulfur:derived almost exclusively from proteins, and yet only 2 of the 20 amino acids normally present in proteins contains sulfur.

Fluoride: Tea which concentrates fluoride in its leaves, and marine fish that are consumed with their bones (e.g., sardines)

Magnesium: greens, nuts, seeds, dry beans, whole grains and low-fat dairy products.

Sodium chloride: Salt

Zinc: beans, nuts, certain types of seafood (such as crab and lobster), whole grains,

Copper:oysters, nuts, seeds, shitake mushrooms, lobster, liver, leafy greens and dark chocolate.

Manganese: whole grains, nuts, leafy vegetables, and teas.

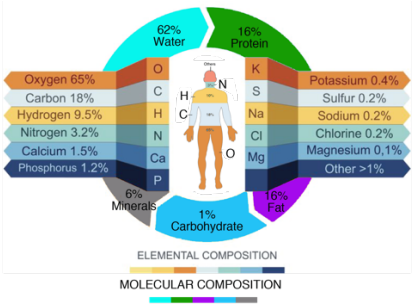
Iodine: seaweed, dairy, tuna, shrimp and eggs.

Selenium: Brazil nuts, tuna, oysters, pork, beef, chicken, tofu, whole wheat pasta, shrimp, and mushrooms.

Chromium: whole-grain products, high-bran cereals, green beans, broccoli, nuts, and egg yolk

Molybdenum: Legumes, such as beans, lentils, and peas

Elemental and molecular composition of our bodies



We are mostly (>60%) water and most of our dry mass consists of Oxygen, Carbon, Hydrogen, and Nitrogen.

Cultural norms, such as vegetarianism in agricultural societies can have strong consequences for certain elements such as iron. This is especially true for women of reproductive age who can experience substantial loss of iron via menstruation.

Practice Question: What is the difference between elemental and molecular composition of the human body?

Answer: Elemental refers to chemical elements (oxygen, carbon, hydrogen etc) whereas molecular refers to type of molecules: water, protein, fat carbohydrate etc.)

Summary

Our bodies are over 2/3 water and some tissues like our eyes are 95% water!

Drier, open environments required our ancestors to look for water sources.

Apes live mostly in forests, where water is easier to find.

Water holes are dangerous due to predator and disease transmission.

Transporting water is tricky, both for humans in a dry environment and for cells in our bodies (aquaporins).

There are 16 essential minerals: calcium, phosphorus, potassium, sulfur, sodium, chloride, magnesium, iron, zinc, copper, manganese, iodine, and selenium, molybdenum, chromium, and fluoride.

Minerals are crucial for our health, they also need to get actively transported across our cell walls.

Both lack and excess of minerals can be dangerous to or health, e.g. sodium, fluoride…

Modern societies are overusing the planets water supplies.

Many people still do not have access to safe water.

Carrying water is mostly a burden of women.

Water is big business and at the root of many conflicts.

We crave salt but are using about 3 times as much as we should for cardiovascular health.