This Week

Living in Water

For animals that live in water, the rules are different.

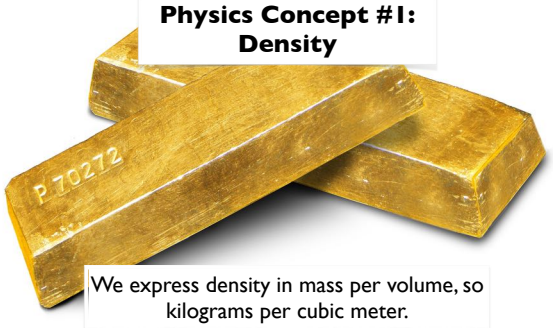
Special properties of water

- It's dense.
- It's sticky.
- It has a high heat capacity, a high heat of vaporization, and a high thermal conductivity.
- It dissolves oxygen and other gases. Cold water dissolves more.
- It's electrically conductive.

Metric Units

1 kilogram (kg) is about 2 pounds
1 meter is about 1 yard
1 cubic meter (m^3) is about 1 cubic yard
1 cubic meter (m^3) is 1000 liters or about 250 gallons

Physics Concept #1: Density



We express density in mass per volume, so kilograms per cubic meter.

Density

Substance	ρ (kg/m^3)
Hydrogen gas (20°C)	0.083
Helium gas (20°C)	0.166
Air (20°C)	1.20
Air (0°C)	1.28
Gasoline	680
Ethyl alcohol	790
Oil (typical)	900
Water	1000
Seawater	1030
Blood (whole)	1060
Glycerin	1260
Mercury	13,600

Body Component	Density (kg/m^3)
Fat	900
Water	1000
Blood	1050
Muscle	1060
Bone	1280

Fat is less dense than water, muscle is more dense than water.

Gold is very dense.

7 inches long, 3½ inches wide, 1 ¾ inches deep
27 pounds

From Wikipedia

Gold cost $38.69 per troy ounce in 1968, so four million dollars in gold bars would have weighed about 3,200 kg (7,100 lb), requiring each of the three Minis to carry about 1,070 kg (2,360 lb) in addition to the driver and passenger. Since a 1968 Mini only weighs 630 kg (1,390 lb), each of these vehicles would have had to carry 1½ times its own weight in gold.

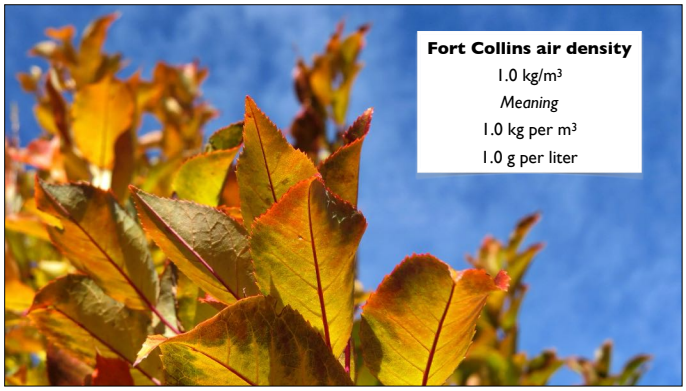
The Italian Job

Water density

1000 kg/m^3

meaning

1.0 kg per liter



Pressure

The air at the earth's surface supports the weight of all the air above it: That's the source of atmospheric pressure.

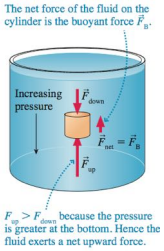
We define the pressure at sea level as **1 atmosphere**.

Pressure vs. Height

As you go higher in the atmosphere, the pressure is lower.

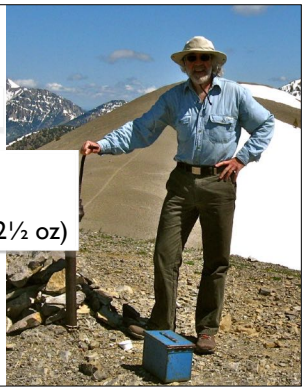
Buoyancy

The buoyant force is equal to the weight of fluid displaced.



Question:
Taking buoyancy into account, is the reading on the scale greater than, equal to, or less than your actual weight?

Submerged in Air



My volume: 70 liters
Mass of air displaced: 70 grams
Buoyant force: 70 grams (2½ oz)

My mass: 70 kilograms
My volume: 70 liters
Mass of water displaced: 70 kilograms
Buoyant force equals weight force!

Submerged in Water

Balloon volume: 12 liters
Mass of air displaced: 12 grams
Mass of balloon: 1 g
Mass of helium in balloon: 2 grams
Total lift: 9 grams (⅓ oz)

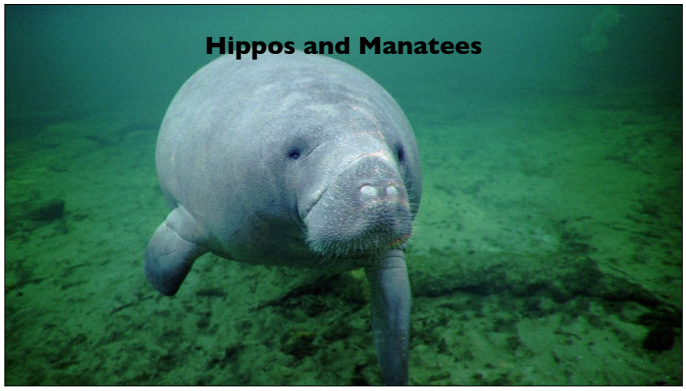
If the buoyant force is larger than the weight...

$\rho_f > \rho_o$: floaty

$\rho_o > \rho_f$: sinky

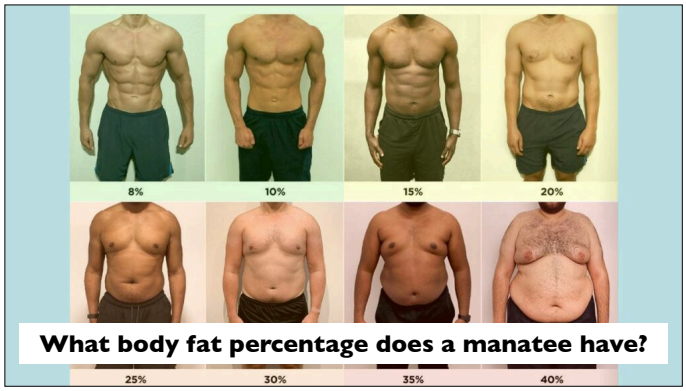
If an object is more dense than the fluid it is submerged in, it sinks.
If an object is less dense than the fluid it is submerged in, it floats.

Hippos and Manatees



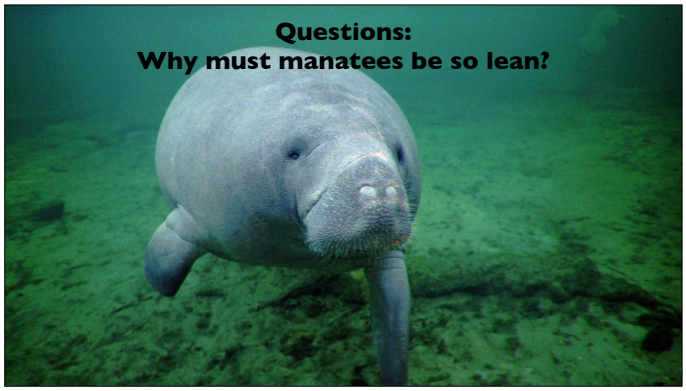
Hippos Can't Swim

Despite appearances, hippos have very little body fat. The density of a hippo's body is approximately 1030 kg/m³, so it sinks to the bottom of the freshwater lakes and rivers it frequents—and then it simply walks on the bottom.



What body fat percentage does a manatee have?

Questions:
Why must manatees be so lean?



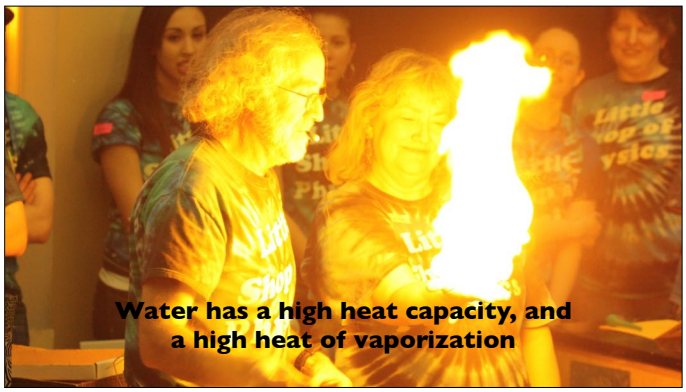
Manatees

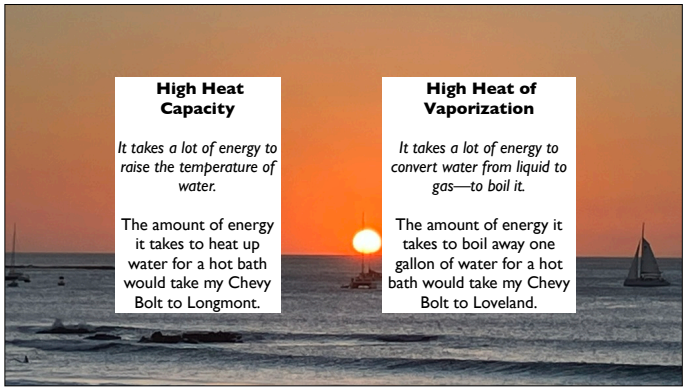
Very low energy food sources, and so very slow metabolism (half a typical mammal of the same size)

Adaptations for efficient movement

- Almost neutral buoyancy
- Solid bones on lower parts, lungs long, horizontal, high along back. Two diaphragms control lung volumes separately
- Perhaps can control volume of gas in large intestine

At the surface of the ocean, if I take a deep breath (about 4 liters, I figure) I float easily. If I hold my breath and dive to a depth of 10 m, if I stop swimming, I sink.





High Heat Capacity

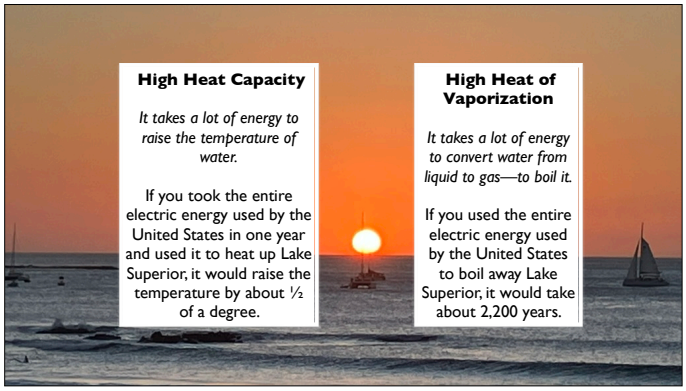
It takes a lot of energy to raise the temperature of water.

The amount of energy it takes to heat up water for a hot bath would take my Chevy Bolt to Longmont.

High Heat of Vaporization

It takes a lot of energy to convert water from liquid to gas—to boil it.

The amount of energy it takes to boil away one gallon of water for a hot bath would take my Chevy Bolt to Loveland.



High Heat Capacity

It takes a lot of energy to raise the temperature of water.

If you took the entire electric energy used by the United States in one year and used it to heat up Lake Superior, it would raise the temperature by about ½ of a degree.

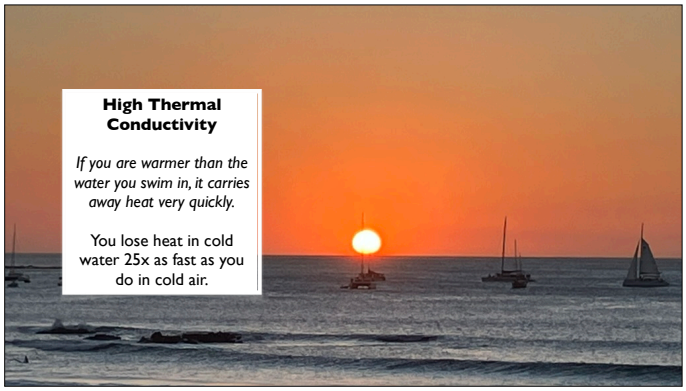
High Heat of Vaporization

It takes a lot of energy to convert water from liquid to gas—to boil it.

If you used the entire electric energy used by the United States to boil away Lake Superior, it would take about 2,200 years.

Thermal Conductivity

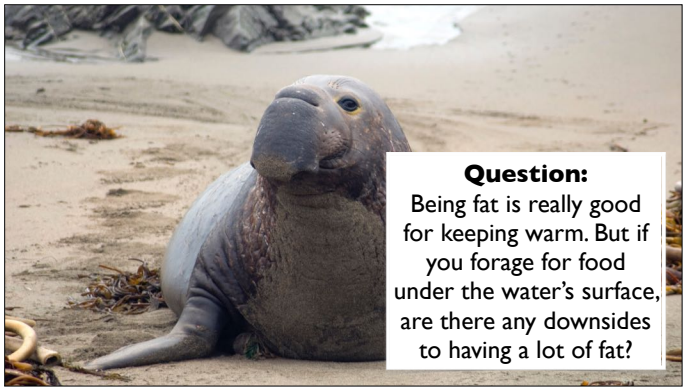
Which feels colder—standing on a cold tile floor or a cold carpeted floor?



High Thermal Conductivity

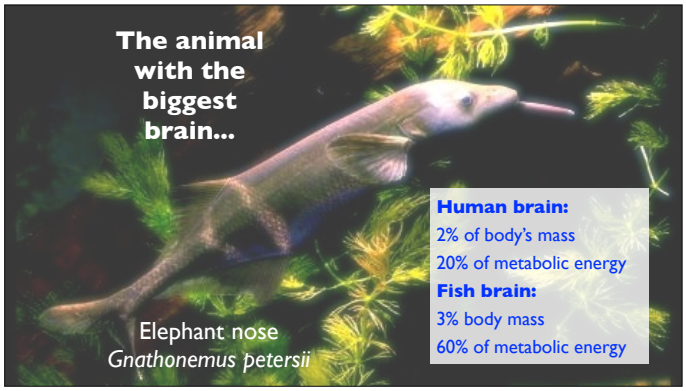
If you are warmer than the water you swim in, it carries away heat very quickly.

You lose heat in cold water 25x as fast as you do in cold air.



Hellbender salamander
½ meter long
No lungs, no gills. "Breathes" through the skin

Question:
Why is the hellbender so wrinkly?

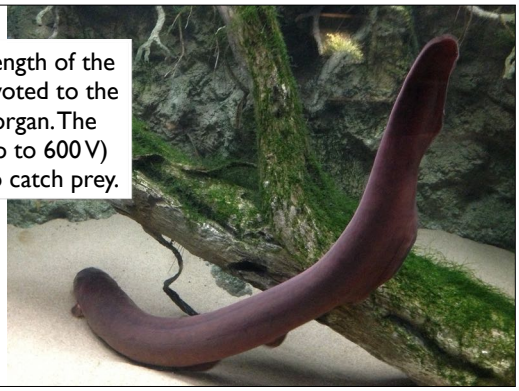


You don't lose 20% (or 50%) of your heat through your head.

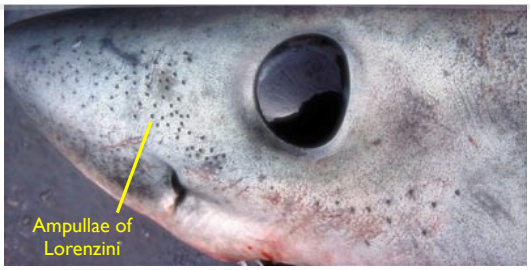
Your blood keeps your body temperature pretty uniform. Your head is about 10% of your body's area, but much of it is covered with hair, so you lose about 7-10% of heat through your head.

OK, so a bit more loss for some.

⅘ of the length of the body is devoted to the electric organ. The shocks (up to 600 V) are used to catch prey.



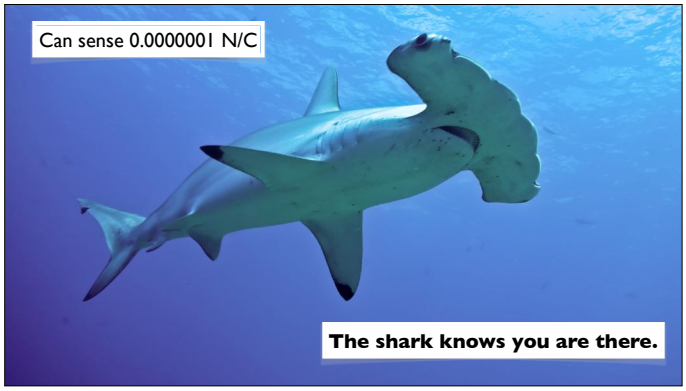
Animals with electric sense can detect electric fields.



Sharks and rays have an exquisite electric sense, but other animals do this as well.

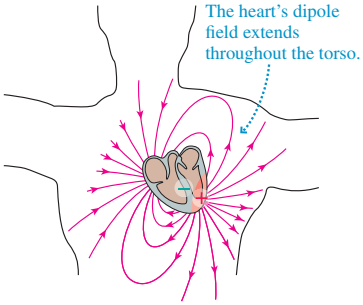
Wide head means greater sensitivity, and also scanning a wider swath.

Can sense 0.0000001 N/C

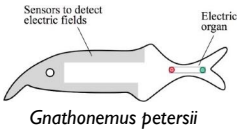


The shark knows you are there.

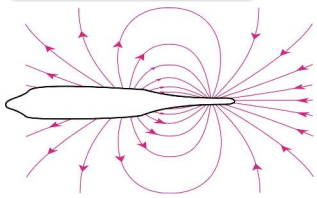
Your heart makes one electric field when it beats.



Elephant nose sensory system



Gnathonemus petersii



The presence of a conducting object (like another fish) will alter the field lines. The fish can sense this change.

Decoding this signal requires a really big brain.

These fish are bright, sociable, and have individual personalities.