

This Week: Living In Water

Hippos can't swim, and manatees aren't fat. For creatures that live and move in water, the details of existence are quite different than for those of us who spend our days on land, and there are some real surprises in how these creatures get around. The buoyant force balances the force of gravity, and motion up and down—diving and then surfacing—requires special adaptations. And some creatures are able to live at the boundary between air and water, an even more remarkable feat. We'll discuss all this, and more.



The animal with the biggest brain...

Elephant nose
Gnathonemus petersii

Human brain:
2% of body's mass
20% of metabolic energy
Fish brain:
3% body mass
60% of metabolic energy

Special properties of water

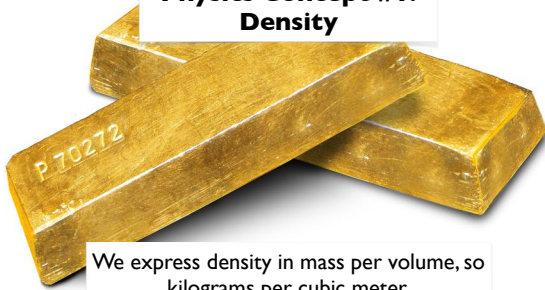
- It's dense.
- It's sticky.
- It has a high heat capacity, a high heat of vaporization, and a high thermal conductivity.
- It dissolves oxygen and other gases. Cold water dissolves more.
- It's electrically conductive.

Metric Units

1 kilogram (kg) is about 2 pounds
1 meter is about 1 yard
1 cubic meter (m³) is about 1 cubic yard
1 cubic meter (m³) is 1000 liters or about 250 gallons



Physics Concept #1: Density



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

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

Density

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, 1¾ 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/m³
meaning
1.0 kg per liter

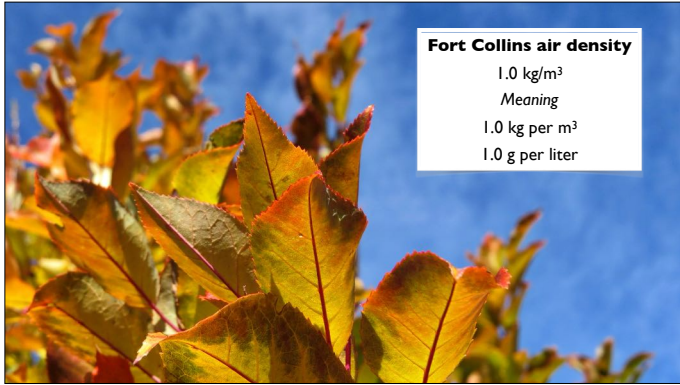


Mass

25 kg

Volume

25 liters

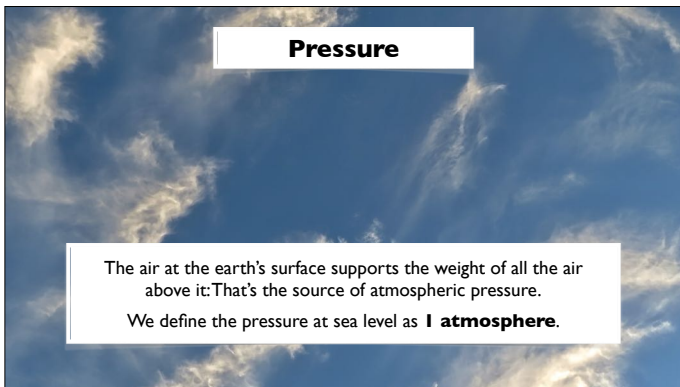


Fort Collins air density

1.0 kg/m³
Meaning
1.0 kg per m³
1.0 g per liter

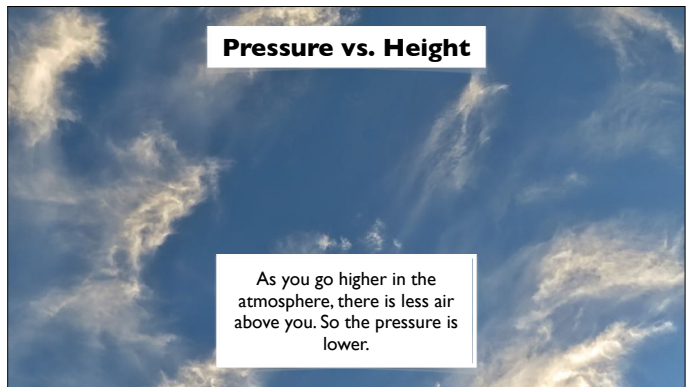


Air has mass.



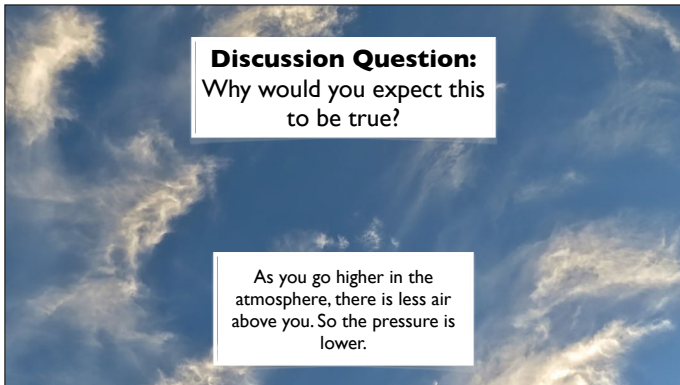
Pressure

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

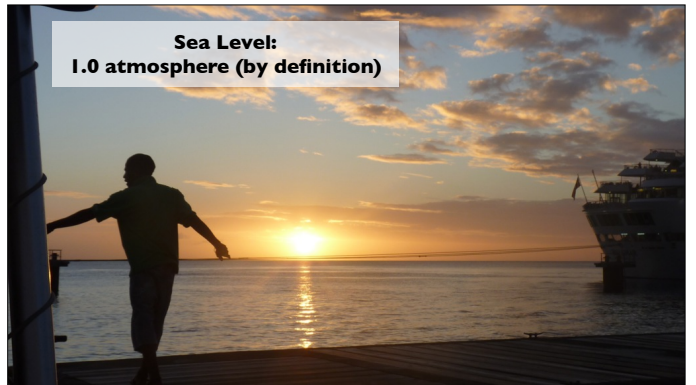
As you go higher in the atmosphere, there is less air above you. So the pressure is lower.



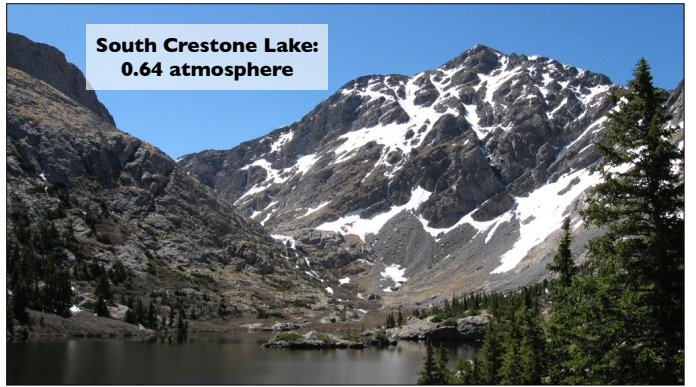
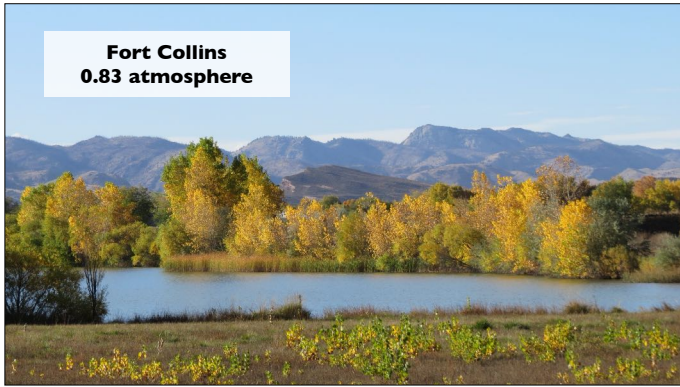
Discussion Question:

Why would you expect this to be true?

As you go higher in the atmosphere, there is less air above you. So the pressure is lower.



Sea Level:
1.0 atmosphere (by definition)



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
Bouyant 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 (1/3 oz)

↑
Enough to lift 4 dimes



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 can't swim.
Manatees aren't fat.**



Hippos spend much of their lives in water, but amazingly, they don't swim.

Despite appearances, they 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.




They have about 7% body fat.



Manatees

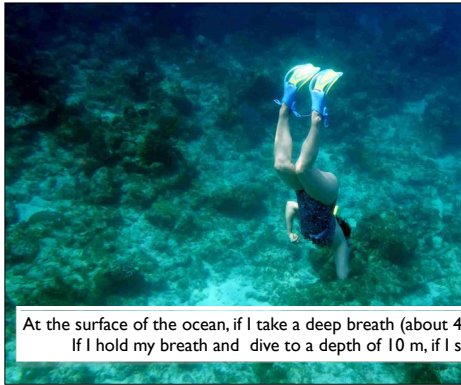
Very low energy food sources, and so very slow metabolism (half a typical mammal of the same size)



From Crystal River, Florida

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



Question:
 Why does this happen?
 (Hint: What happens to the size of my lungs as I dive? How does this affect my density?)

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.

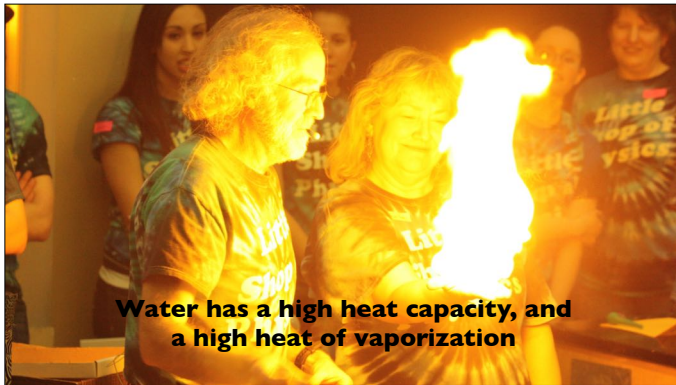
Water is sticky.



Magic Sand



Floating a coin



Water has a high heat capacity, and a high heat of vaporization

TABLE 12.7 Thermal conductivity values (measured at 20°C)

Material	k (W/m · K)	Material	k (W/m · K)
Diamond	1000	Skin	0.50
Silver	420	Muscle	0.46
Copper	400	Fat	0.21
Iron	72	Wood	0.2
Stainless steel	14	Carpet	0.04
Ice	1.7	Fur, feathers	0.02–0.06
Concrete	0.8	Air (27°C, 100 kPa)	0.026
Plate glass	0.75		

Notice the difference between muscle and fat.

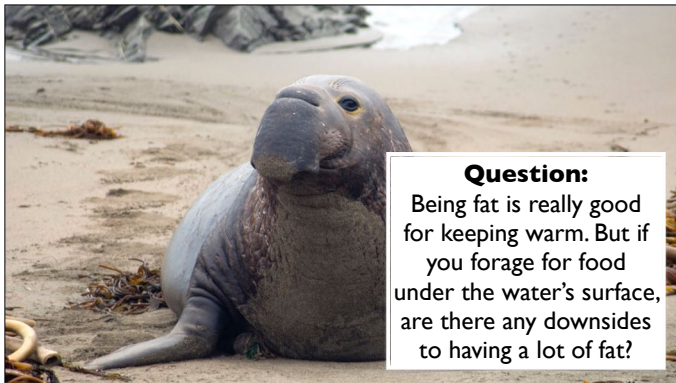
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Why do fur and feathers have such low thermal conductivity?



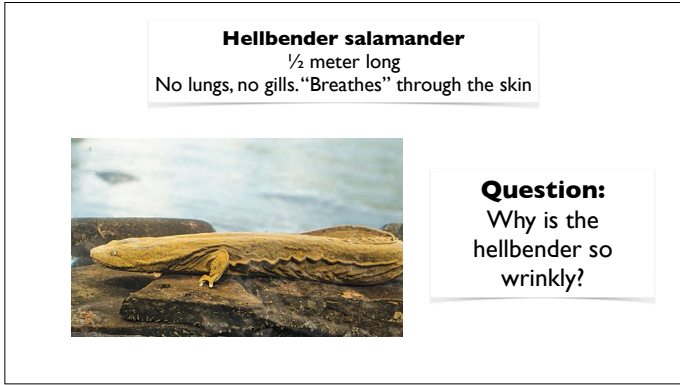
If you live in water, fat and fur keep you warm.



Question:
Being fat is really good for keeping warm. But if you forage for food under the water's surface, are there any downsides to having a lot of fat?



Fat and Floaty

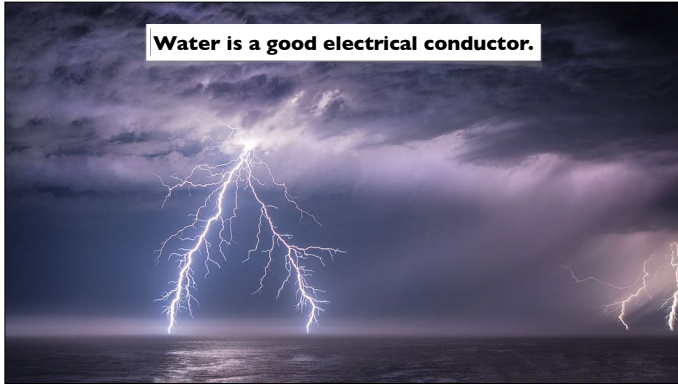




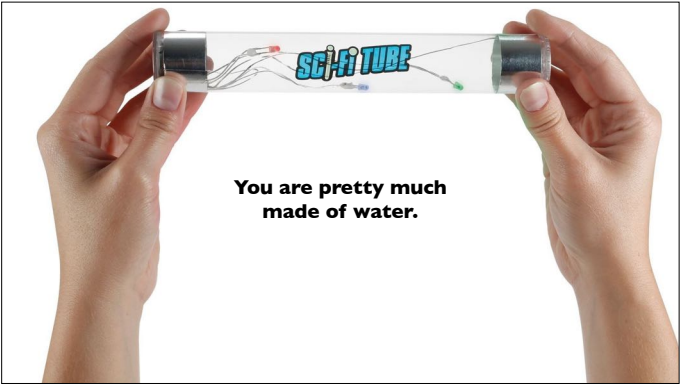
Question:
What mammal gets the most of its oxygen through its skin?



10% of respiration through skin at rest



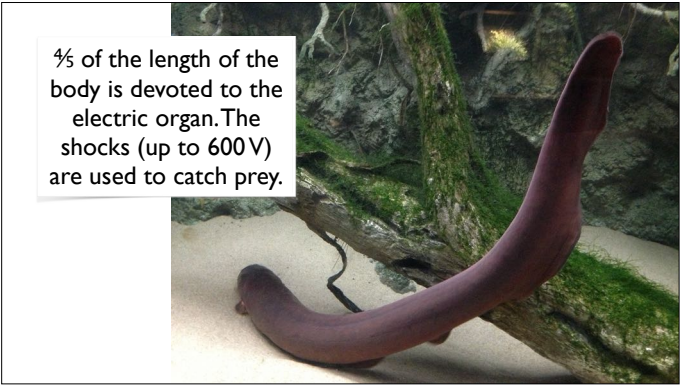
Water is a good electrical conductor.



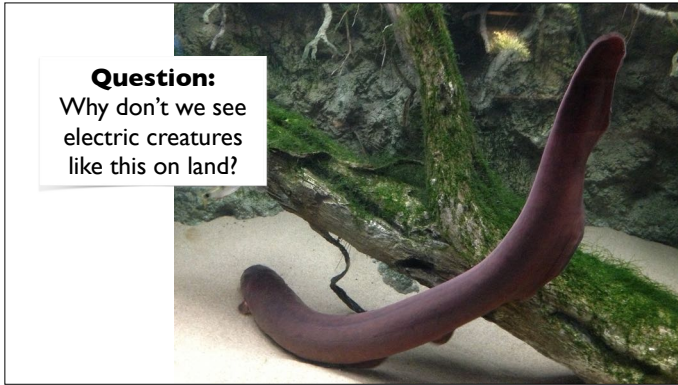
You are pretty much made of water.



Strongly Electric Fish



4/5 of the length of the body is devoted to the electric organ. The shocks (up to 600 V) are used to catch prey.



Question:
Why don't we see electric creatures like this on land?



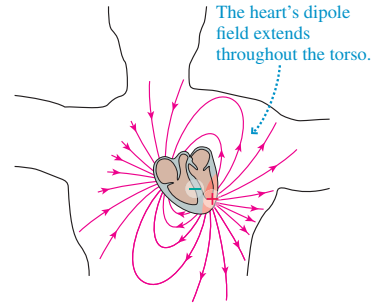
Weakly Electric Fish

Animals with electric sense can detect electric fields.

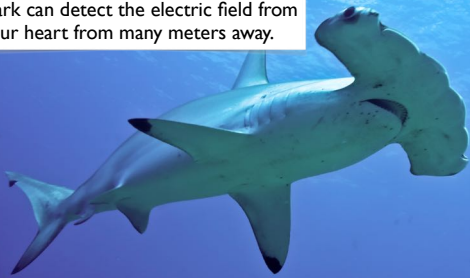


Sharks and rays have an exquisite electric sense, but other animals do this as well.

Your heart makes one electric field when it beats.



A shark can detect the electric field from your heart from many meters away.



The shark knows you are there.

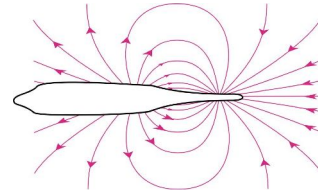
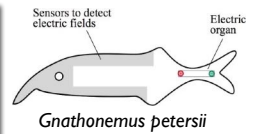
Wide head means greater sensitivity, and also scanning a wider swath.



Some mammals can do this too.

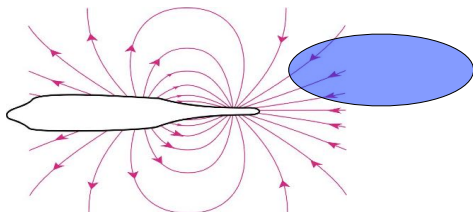


Elephant nose sensory system



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

The presence of another fish (whose body is a better conductor than fresh water) affects the field.



Decoding this signal requires a really big brain.

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

