EPISODE FIVE

RESOURCE PACK

ACTUALLY, IT'S PHYTO-PLANKTON!

MEET RYAN VANDERMEULEN
Skateboarding Scientist

This is Ryan, from NASA Goddard Space Flight Center's Ocean Ecology Laboratory. If he could, he'd skateboard to work every day. But it's a bit tricky on the Beltway (which is a massive highway surrounding Washington DC in the USA).
Ryan is our favourite person to talk to about physics in the ocean. Ryan's favourite food is Kimchi (YUM!).

MEET LACHLAN MCKINNA
Cycling Scientist

both oceanographers both physicists

You know Lachlan as a regular podcast co-host. He likes gardening and cycling. Physics is his thing, especially when it has to do with oceanography. Lockie's favourite food is the classic meat pie.

Image Credit: Ryan Vandermeulen

Image Credit: Lachlan McKinna

That's Physics Baby!

You don't need to be a "do all the maths in your head" type of person to be good at physics. Lachlan explains that physics is the study of matter (that is the stuff we're made of, aka atoms) and how they interact with the universe around us. Physicists think of the world in terms of forces and energy and mathematics is the language they use to describe that physical world. For example, imagine a hot coffee on your desk. Eventually it's going to go cold, right? In the study of physics, we could describe how long it would take for the thermal energy to be lost from the cup and eventually end up at room temperature. To do that we need to know information about the system (that is: the coffee cup, the beverage inside, and the room where the cup exists). Once we have the information needed, we can create a mathematical model that describes precisely how long it will take for the coffee to go cold.

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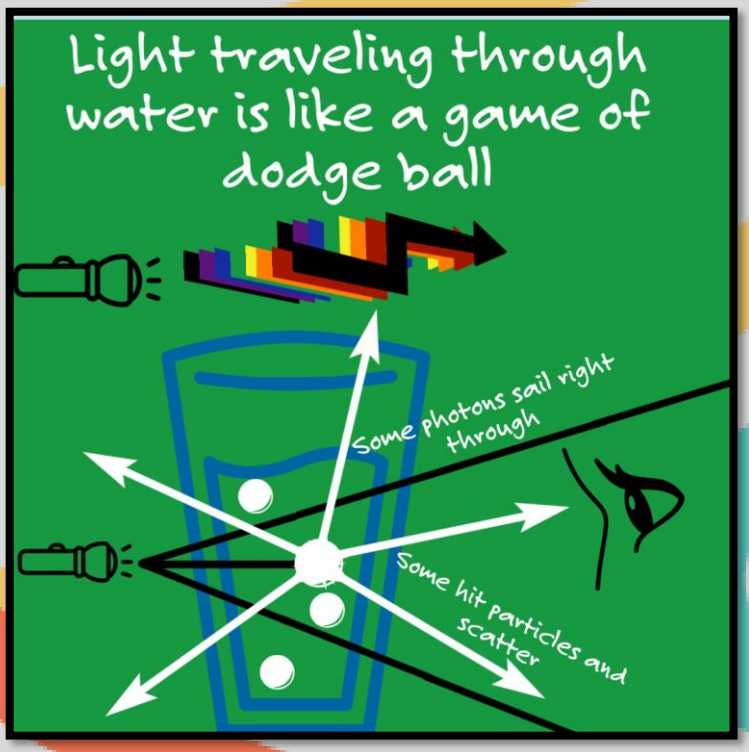
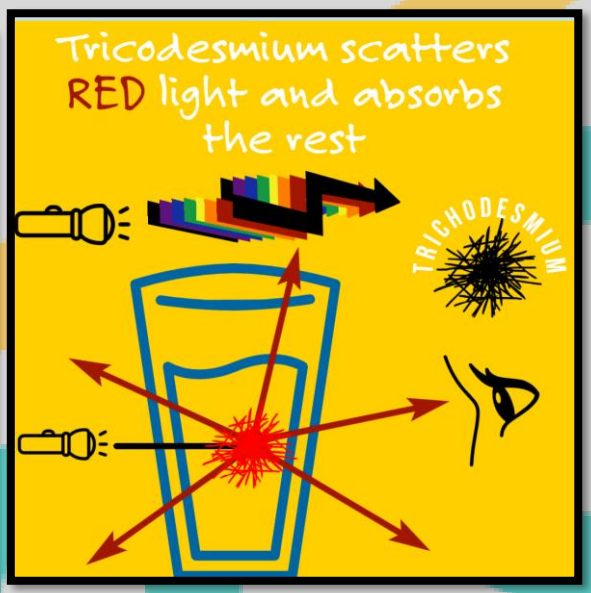
LIGHT SCATTERING

Imagine you're getting ready to play a game of dodge ball. There is an empty hall, and all the balls are lined up ready to play. Right now, there is no one on the court to hit with a dodge ball. But you throw the balls across the room anyway and they just travel straight through. This is what light does when it's travelling through a vacuum. There are no particles of other stuff to hit, so the light travels straight through.

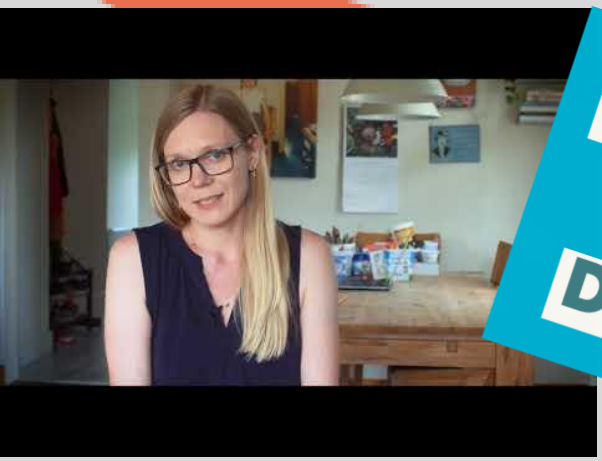
Now, some players drop into the dodgeball court, and you start to play for real. You're throwing dodgeballs like a champ. Some miss and travel straight through, but others hit their target and bounce off the players in all directions.





LIGHT ABSORBTION

Most particles will do a combination of absorption and scattering so that our eyes see their complex colour.



Video 1: Click image above to play

Play Milk & Water Dodgeball

Video 2: Click image above to play

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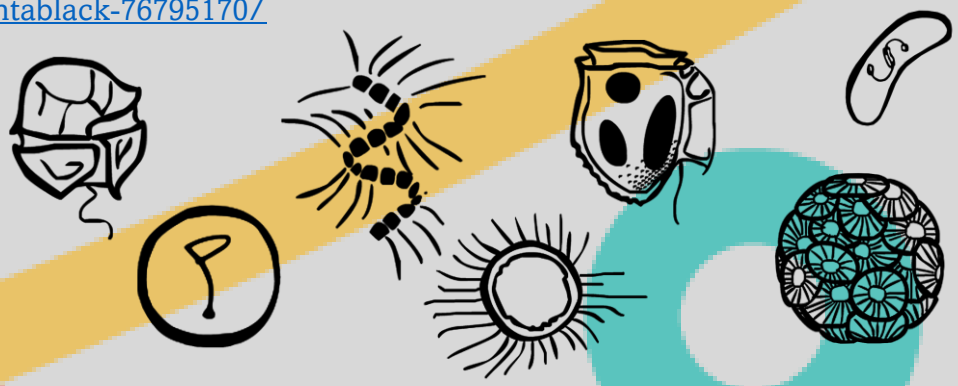
VANTA Black

Vantablack is one of the world's darkest substances, absorbing 99.9% of light that touches it. VANTA stands for "vertically aligned nanotube arrays," and it is basically a standing forest of billions of super small tubes that work to trap any light that hits it and bounce it around until that energy is eventually dissipated into heat. This might seem like a simple novelty, but it's a pretty useful substance that can, for example, help prevent stray light from getting into a space telescope. Listen to Stuff You Should Know podcast for more: https://www.iheart.com/podcast/105-stuff-you-should-know-26940277/episode/short-stuff-vantablack-76795170/

Video 3: Click image above to play



Phytoplankton catch & deflect

Phytoplankton can't conscientiously select their favorite colors of light, because they are mostly free-floating and have no brains. But within each phytoplankton cell are a series of light-harvesting pigments that help them ABSORB specific colors of sunlight and convert that light energy into chemical energy through photosynthesis. One pigment common to all plants is called chlorophyll, and it absorbs red and blue light very efficiently, but it does NOT absorb green light. Thus, we see most plants as green because it is the only color of light remaining to be scattered back to our eyes.

But chlorophyll isn't the only pigment absorbing light, there are some pigments that have other functions. Some pigments are specifically meant to capture other colors of light that are less utilized, and there are other pigments, for example, that can prevent cells from becoming sunburned. So, every phytoplankton cell is absorbing and scattering light in a unique way depending on a distinct combination of what pigments it contains, as well as its size and shape, and what it is made out of.

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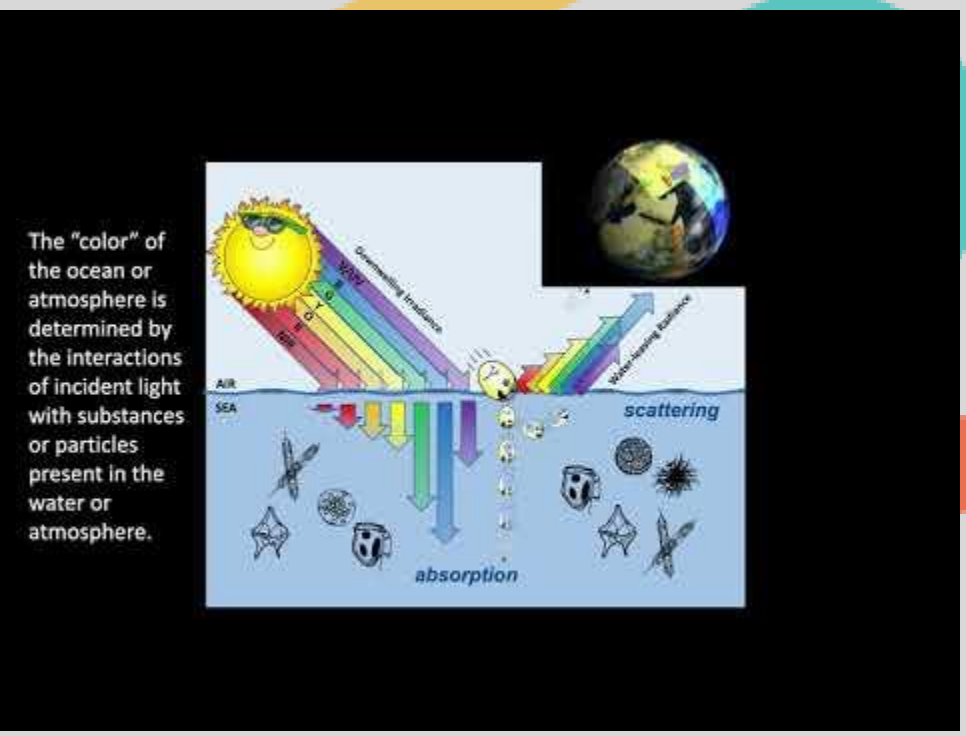
Using physics to study the ocean

While it is no Vantablack, the ocean still absorbs the greatest amount of solar radiation that reaches the Earth's surface. This is important because virtually all the energy used by any living organism on Earth (including us) started out as sunlight absorbed by phytoplankton, land plants, or other organisms that have this amazing ability to convert light energy into a form that we can use. Phytoplankton in the ocean play an enormous role in the history of this energy cycling on our planet, and without absorption and scattering, life as we know it would not exist.

Now, to be a little less dramatic… One of the most exciting advances in oceanography has been the ability to measure changing color over wide swaths of the ocean, using Earth-orbiting satellites that measure light reflected from the surface layer of the ocean. The manner in which light is scattered and absorbed in the ocean changes the color of the water, which, among other things, directly indicates changes in the global distribution of phytoplankton. Thanks to absorption and scattering, we can see how phytoplankton populations bloom, collapse, and change over time in any area, which has really revolutionized how we think about the upper ocean.

Want to know more? Go back to season 1: Actually, it's Phytoplankton! Ocean Ecology & NASA's PACE Mission



Video 4: Click image above to play

Review with this game!

Choose to play in jeopardy or choice mode. Great to use the classroom as a review game. https://www.playfactile.com/lightandwater

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Fluorescence

Glow sticks are a great example of **chemical florescence**. In a glow stick there are two tubes. The outside plastic tube has **florescent dyes** and a substance called **tert-butyl alcohol**. On the inside of that plastic tube there is another very fine glass tube with a chemical in it called **hydrogen peroxide** that you release into the plastic tube when you crack it.

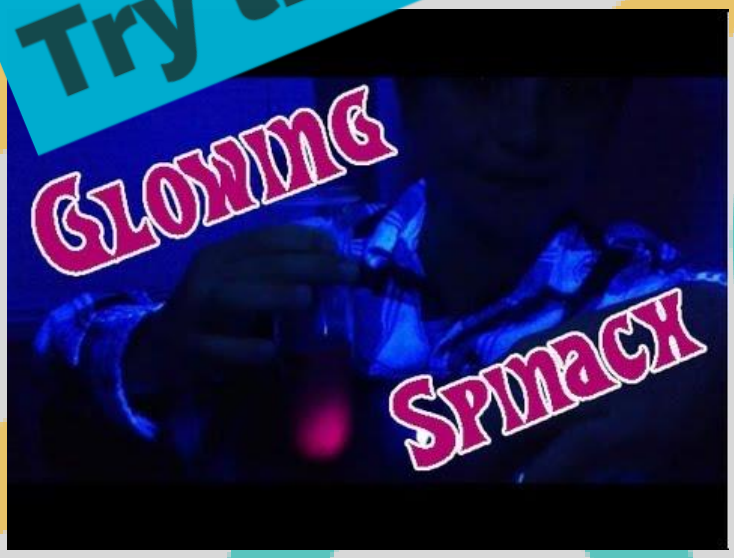
REMEMBER! Don't chew the tube!

When those materials combine, they cause a **chemical reaction** which makes the electrons in the dyes excited. Excited electrons are a bit like toddlers. They bounce around and have heaps of energy. Seemingly, endless energy… Some of that energy escapes and gets emitted as light.

That's called chemiluminescence. And unfortunately, it's not the type of florescence that is particularly important for oceanography.

Oceanographers are interested in the fluorescent qualities of **chlorophyll**.

Try this!



Video 5: Click image above to play

"Go on with the chlorophyll!"

It is important to remember that energy cannot be created or destroyed. That's the first law of thermodynamics! We already know that phytoplankton are obtaining energy from the Sun, and they convert that light energy into usable chemical energy with the help of our super molecule, **chlorophyll**. Remember those excited electrons in the glow stick that we mentioned? Well, when sun light hits a chlorophyll molecule the electrons within it are also being excited and something needs to happen with that energy. It can't stay bundled up for too long. A phytoplankton cell will work to use this energy so it can do cool things like grow, divide, live, etc. But, in some cases, if the cell can't use all that energy, well, they can't destroy it, so they actually release it back again. When this happens, because some energy has been lost to heat and other processes within the cell, the light that is released is somewhat different. Since it has lost some energy, the light is emitted at a longer, lower-energy wavelength than when it was first absorbed, meaning, literally that they glow a faint shade of red. Unlike the chemical glow stick, phytoplankton need light for this reaction to happen, so once the light it gone, fluorescence stops. So, it is not easy to detect and measure fluorescence unless you know exactly what you are looking for.

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Apply physics concepts in ocean science

So even though we're only examining the physics of light moving around in the ocean, it holds a direct link to the microscopic composition of the ocean. The quality of light is being changed as it is absorbed, scattered, and fluoresced about. By measuring these unique light physics (aka "optical") properties of seawater, we can gain some insights as to what types of phytoplankton and other materials are present. One important way that we apply this knowledge is to help us understand, monitor, and predict environmental change. Since phytoplankton depend upon sunlight, water, and nutrients to survive, any changes to the ocean environment can have a significant impact on phytoplankton populations, and thus the quality of light in the ocean. This can serve as an alert system to Earth scientists, letting them know where conditions are changing. Then, by comparing optical trends to other measurements, such as temperature, we can learn more about how phytoplankton may be contributing to, and are affected by, climate and environmental change. All brought to you by the 3 fundamental properties of **absorption**, **scattering**, and **fluorescence**.

What do phytoplankton barf up?

Only a specific amount of energy is required for photosynthesis to occur, and getting more energy than that really isn't helpful, in fact, it can be harmful, and actually damage the cell. Think about how we get energy, by eating. We can't just continuously scarf snacks 24/7, and if we did, our body would, ahem… have a means of expelling the excess energy… You'd barf, right? These phytoplankton usually aren't able to move around, so they are essentially stuck eating sunlight all day, and they need some way for their body to barf sunlight (which is to fluoresce)

If a phytoplankton is doing nothing but barfing (aka fluorescing), it means that they aren't using that energy to feed themselves. If we measure the faint glow that phytoplankton give off when they are fluorescing, we can gain insight into how efficiently they are using sunlight that they absorb. Remember, photosynthesis requires more than just sunlight, phytoplankton need nutrients in the mix, just like plants in your garden need to be fertilized. If the ocean doesn't have the essential nutrients needed for growth, the phytoplankton can get stressed, and scientists can measure this. By and large, we want healthy phytoplankton, because they support a healthy ecosystem, and a healthy world.

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Bibliography

Information in this resource pack has been gathered from interviews with expert guests and then transcribed (not verbatim). All still Images are public domain or credited where appropriate. We do not claim ownership of any videos in this pack. Links to all videos are detailed below.

Video Links

1. Tyndall Science at Home - Tyndall Effect Light in a Jar Experiment - YouTube
2. Understanding Absorption of Light - Why do we see different colors? - YouTube
3. VANTABLACK - The Darkest Material on Earth - YouTube
4. Keeping PACE with NASA's Plankton, Aerosol, Cloud, ocean Ecosystem mission - YouTube
5. GLOWING SPINACH Easy Kids Science Experiments - YouTube

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