MOLECULAR TALES

OF MARINE DISSOLVED ORGANIC MATTER

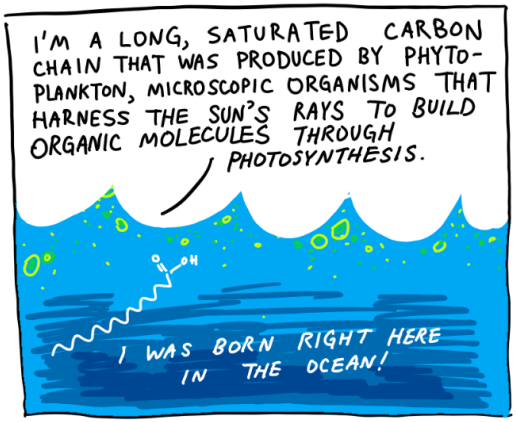
A ZINE ABOUT CHEMISTRY, ADVENTURE, AND THE DEEP BLUE SEA!

BY
EVELYN PAE
SASHA WAGNER

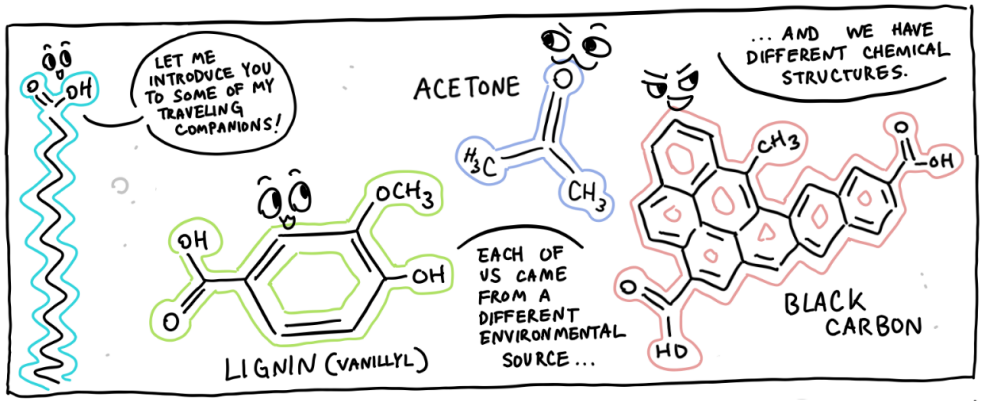
DEEP IN THE OCEAN...

...EXISTS ONE OF EARTH'S LARGEST ORGANIC CARBON RESERVOIRS: MARINE DISSOLVED ORGANIC MATTER, OR DOM.

THE MOLECULES THAT MAKE UP DOM* CYCLE IN AND OUT OF THE OCEAN'S DEPTHS, DRIVEN BY A COMPLEX ARRAY OF BIOLOGICAL, CHEMICAL, AND GEOLOGICAL PROCESSES.



CARBON CYCLING IN THE OCEAN IS A DYNAMIC PROCESS - MOLECULES CAN BE BROKEN DOWN WITHIN MINUTES, OR IT CAN TAKE AS LONG AS A FEW THOUSAND YEARS!

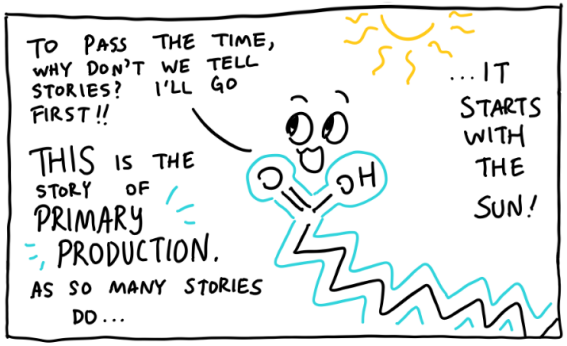


***DEFINITIONS**

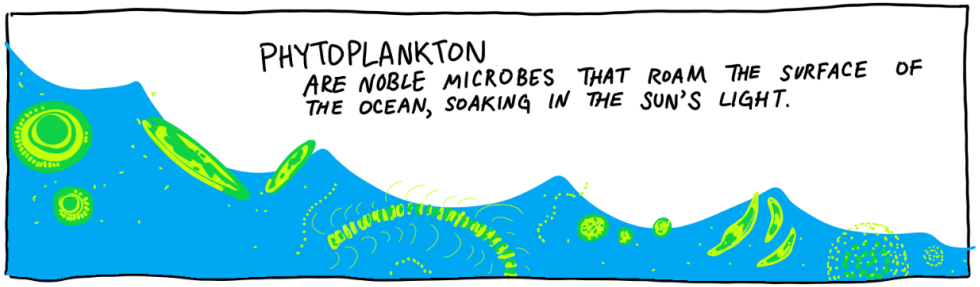
D.O.M. : Dissolved organic matter

D.O.C. : Dissolved organic carbon

Dissolved organic carbon refers to the carbon content of Dissolved organic matter

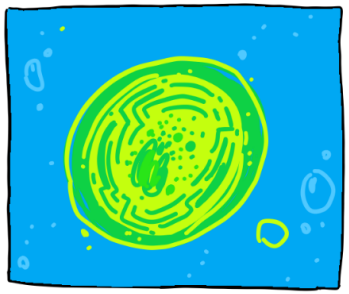


CHAPTER 1: PRIMARY PRODUCTION

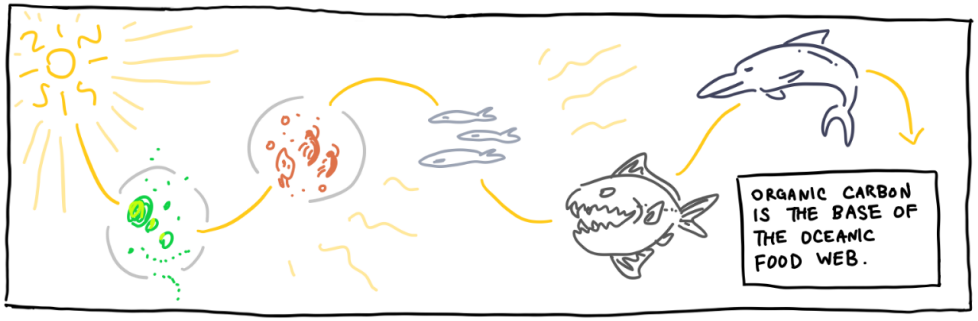


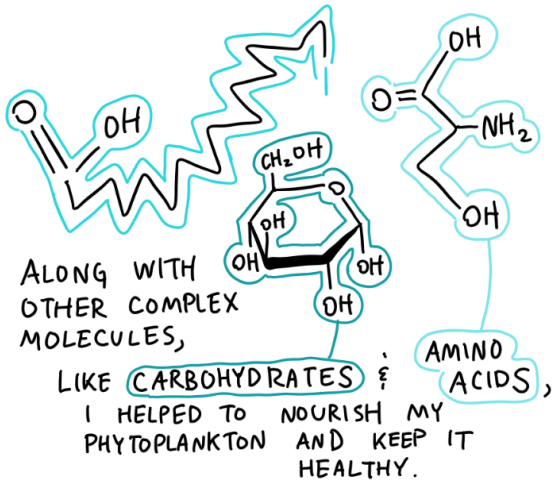
THEIR MISSION IS INCREDIBLY IMPORTANT:

THEY ARE THE PRIMARY PRODUCERS OF THE OCEAN.

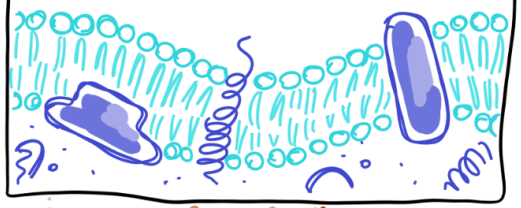


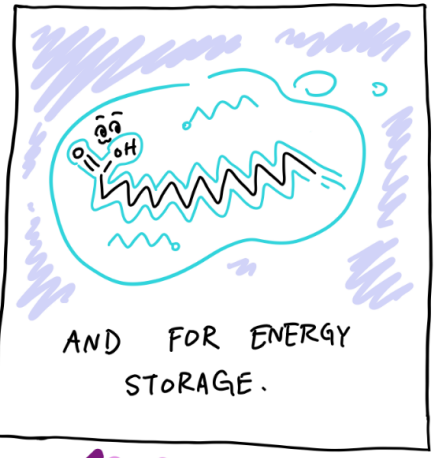
THIS MEANS THAT THEY CAN USE THE SUN'S RADIANT ENERGY TO CREATE ORGANIC CARBON FROM CARBON DIOXIDE.



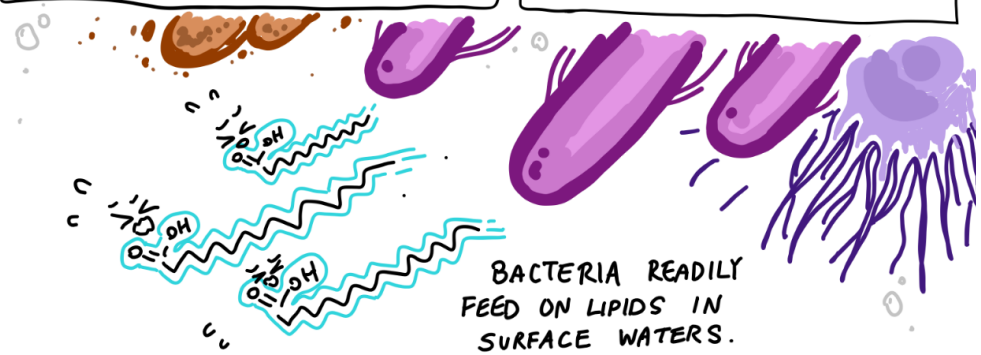


LIPIDS LIKE ME ARE USED FOR STRUCTURE IN CELL MEMBRANES

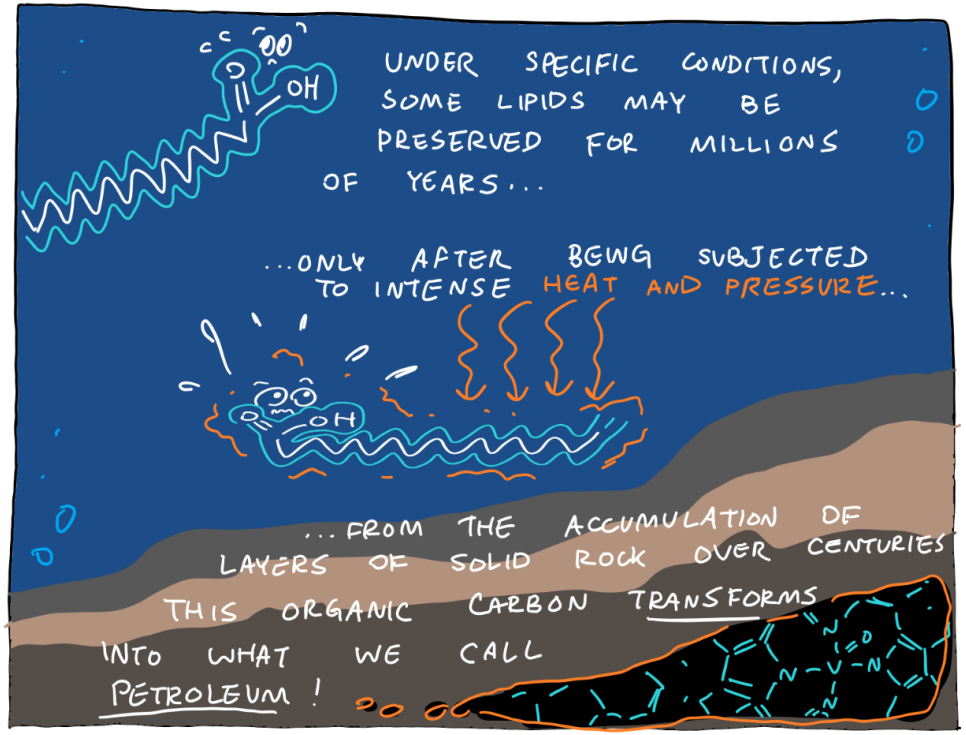




AND FOR ENERGY STORAGE.



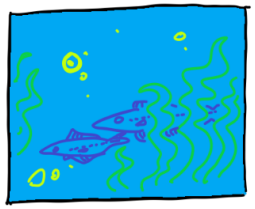
BACTERIA READILY FEED ON LIPIDS IN SURFACE WATERS.



Productivity

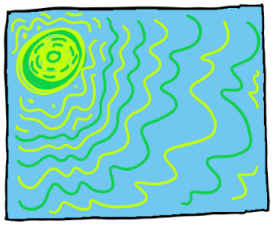
FOR THE MODERN PHYTOPLANKTON: LIVING YOUR BEST LIFE IN THE PHANEROZOIC EON

WHAT IS BIOLOGICAL PRODUCTIVITY?

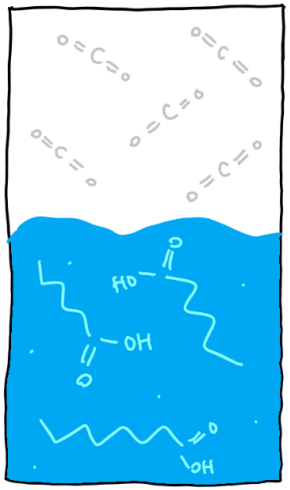


PRODUCTIVITY IS OFTEN MEASURED IN BIOMASS, OR THE WEIGHT OF ALL BIOLOGICAL MATTER IN AN ECOSYSTEM. PRIMARY PRODUCERS USE WATER, CO_2, SUNLIGHT, AND NUTRIENTS TO PRODUCE THE BASIS OF THE FOOD WEB.

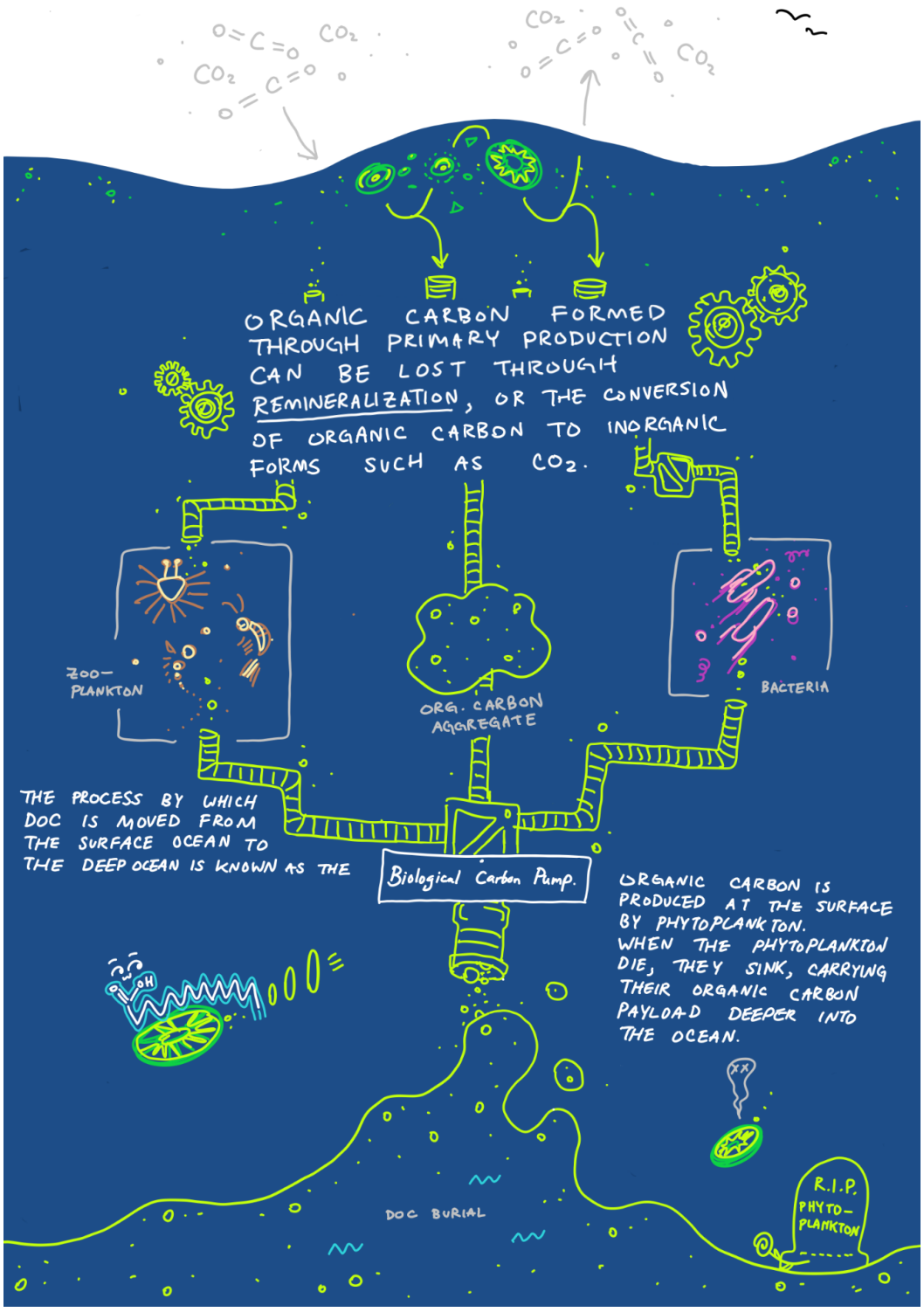
OTHER ORGANISMS CONSUME PRODUCERS IN ORDER TO FUEL THEIR OWN METABOLISMS. A MORE BIOLOGICALLY PRODUCTIVE SYSTEM IS ONE THAT IS CREATING THE MOST ORGANIC CARBON OUT OF RAW INGREDIENTS.

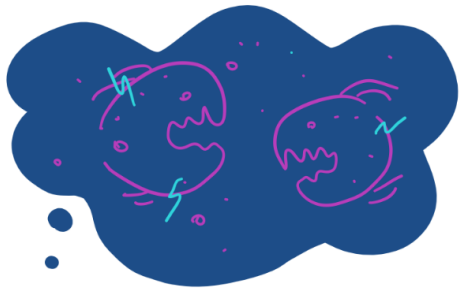


PRODUCTIVITY IS LINKED TO A NUMBER OF FACTORS, SUCH AS TEMPERATURE AND NUTRIENT DENSITY.

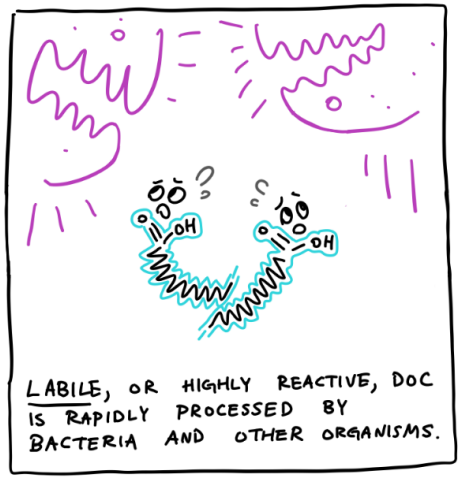


THE BIOLOGICAL CARBON PUMP



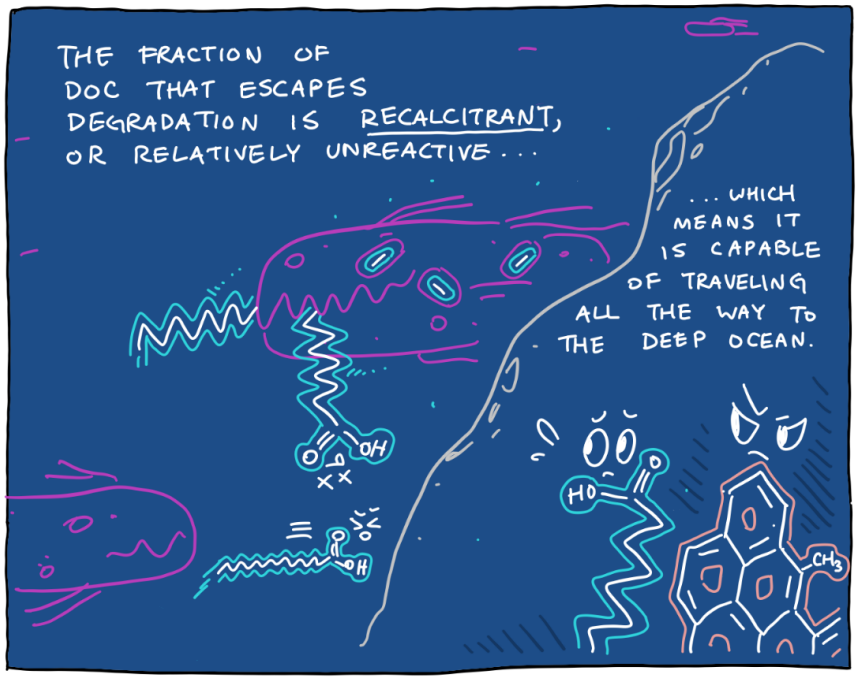


BACTERIA THAT LIVE IN SURFACE WATERS ARE CAPABLE OF BREAKING DOWN ORGANIC CARBON FOR ENERGY IN A PROCESS KNOWN AS RESPIRATION.



LABILE, OR HIGHLY REACTIVE, DOC IS RAPIDLY PROCESSED BY BACTERIA AND OTHER ORGANISMS.

ONLY A NARROW FRACTION OF DOC WILL SURVIVE THESE BIOLOGICAL PROCESSES.



THE SCIENTIST'S PERSPECTIVE

DR LIHINI ALUWIHARE AT THE SCRIPPS INSTITUTION OF OCEANOGRAPHY STUDIES DISSOLVED ORGANIC MATTER AND THE ROLE IT PLAYS IN THE MARINE BIOLOGICAL PUMP, AND MICROBIAL INTERACTIONS.

COMPREHENSIVE GAS CHROMATOGRAPHY – TIME OF FLIGHT MASS SPECTROMETRY — IS USED TO "LOOK" AT MOLECULES. I USE THIS TECHNIQUE TO IDENTIFY INDIVIDUAL MOLECULES WITH SLIGHTLY DIFFERENT CHEMICAL AND PHYSICAL PROPERTIES IN COMPLEX ENVIRONMENTAL MIXTURES (WATER, SOILS, CELLS, ETC). IT FIRST SEPARATES EACH COMPOUND ON TWO DIFFERENT DIMENSIONS — PERHAPS BASED ON EACH COMPONENT'S SIZE AND POLARITY (E.G. HOW MANY OXYGEN ATOMS IT CONTAINS). ONCE SEPARATED, YOU BOMBARD EACH MOLECULE WITH ELECTRONS UNTIL IT BREAKS APART. THE PIECES ARE SHOT DOWN A TUBE AND THE TIME OF FLIGHT THROUGH THE TUBE (CRELATED TO THE MASS OF EACH PIECE) HELPS YOU TO IDENTIFY CHEMICAL STRUCTURES.

BACK TO THE MOLECULES:

... SO TO MAKE IT TO THE DEEP OCEAN, I NEED TO BE A SURVIVOR AND ESCAPE THE FAST RECYCLING OF DOC IN THE SURFACE!

WHO KNEW THERE WAS SO MUCH ACTION GOING ON JUST BENEATH THE OCEAN'S SURFACE!!

LIKE YOU, I ALSO LIVE IN THE SURFACE OCEAN, BUT I CAN COME AND GO AS I PLEASE.

WHILE I'M HERE, LET ME TELL YOU THE STORY OF MY JOURNEY!!

CHAPTER 2: ATMOSPHERICALLY BORNE DOC

MY NAME IS ACETONE, AND I COME FROM THE SKY!!

BEYOND THE REALM OF THE SEA...

... THERE IS A REALM OF THE SKY.

WHEN YOU'RE AS SMALL AND LIGHT A CARBON MOLECULE AS ME, YOU CAN EXIST AS A GAS, HOVERING OVER THE OCEAN.

OTHER AEROSOL MOLECULES ARE CARRIED HERE BY THE WIND AND RAIN.

SURF'S UP!

BREAKING WAVES CAN FACILITATE THE TRANSFER OF ORGANIC AEROSOLS FROM THE SEA TO THE AIR.

AIRBORNE DOC CAN BE PRODUCED THROUGH MANY PATHWAYS.

FOR EXAMPLE, MOLECULES LIKE ME ARE PRODUCED BY PLANTS AND ANIMALS.

WHEN WE FLY OVER THE OCEAN, DENIZENS OF THE SEA CAN SOMETIMES DESCEND TO THE SURFACE AND...

... DISSOLVE.

I CAN BE HELD IN SEA WATER FOR A TIME, BUT BECAUSE, I'M SO TINY & LIGHT...

brrrrrrrrr

... I'LL ALWAYS LONG FOR EVAPORATION!!

ACETONE IS THE MAIN COMPONENT OF MANY NAIL POLISH REMOVERS.

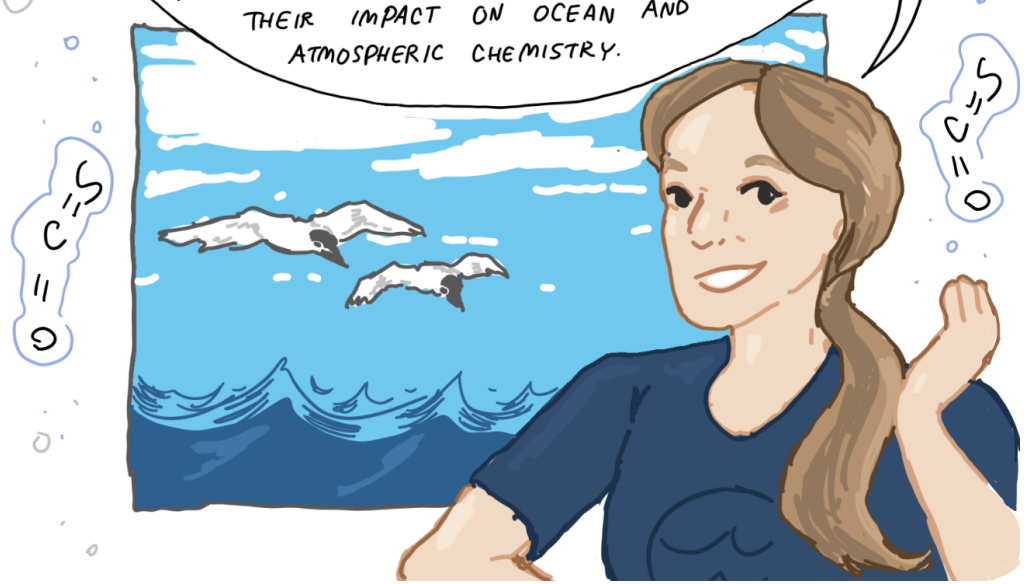
NAIL POLISH REMOVER

I'M JUST BETTER SUITED FOR A GASEOUS LIFESTYLE.

THE SCIENTIST'S PERSPECTIVE:

DR SINIKKA LENNARTZ, OF THE UNIVERSITY OF OLDENBURG, DESCRIBES HER WORK STUDYING ORGANIC GASES:

FOR SEPARATING GASES FROM SEAWATER FOR ANALYSIS, WE CAN USE A SO-CALLED "EQUILIBRATOR". THIS IS LIKE A MINI-SHOWER IN A BOX: SEAWATER DRIZZLES IN LITTLE DROPLETS THROUGH THE EQUILIBRATOR, THEREBY EQUILIBRATING THE CONCENTRATION OF THE GASES IN THE DROPLETS AND SURROUNDING AIR IN A RATIO SPECIFIC TO EACH GAS. WE MEASURE THE CONCENTRATION OF THE GAS IN THE EQUILIBRATED AIR, AND CALCULATE HOW MUCH WAS IN THE SEAWATER. MEASURING THE CONCENTRATION OF CERTAIN GASES IN SEAWATER AND THE OVERLYING ATMOSPHERE ALLOWS US TO ASSESS THEIR FLUX ACROSS THE SEA SURFACE, TO ASSESS THEIR IMPACT ON OCEAN AND ATMOSPHERIC CHEMISTRY.



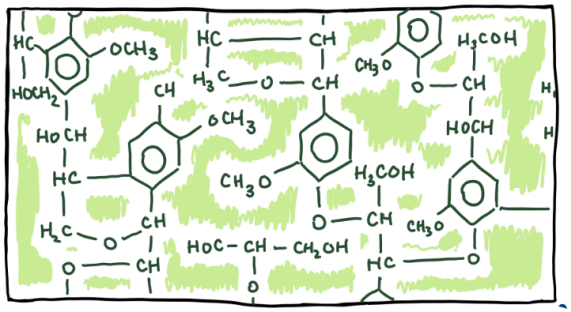
YOU'VE TRAVELED THROUGH THE AIR... AND I'VE TRAVELED ACROSS THE LAND.

WE'VE BOTH COME A LONG WAY TO BE HERE...

NOW, I'LL TELL YOU ABOUT MY JOURNEY THROUGH THE RIVERS!

CHAPTER 3: TERRIGENOUS RIVERINE DOM

MY NAME IS VANILLYL, AND I COME FROM LIGNIN.



LIGNIN IS A LARGE ORGANIC MOLECULE THAT IS PRODUCED BY LAND PLANTS. ORGANIC CARBON THAT'S PRODUCED ON THE LANDSCAPE IS CALLED TERRIGENOUS.

AS VANILLYL, I'M A SMALL MOLECULAR BUILDING BLOCK OF LIGNIN THAT IS PRODUCED WHEN THE LARGER LIGNIN STRUCTURE IS BROKEN DOWN.

IF YOU SEE ME, IT'S LIKELY THAT THE WATER I'M IN HAS TRAVELED FROM A PLACE WHERE TERRESTRIAL PLANTS ARE GROWING.

COASTING DOWN A RIVER TOWARDS THE SEA, I HAVE TRAVELED HUNDREDS OF MILES TO JOIN YOU.

WHEN I WAS PRODUCED INSIDE A PLANT, I WAS USED TO KEEP STEMS AND TRUNKS FIRM AND STRUCTURED.

BUT MY PLANT DIED, I BECAME PART OF THE SURROUNDING SOIL ...

... AND WAS THEN WASHED INTO A RIVER BY RAINFALL.

RIVERS ARE LIKE CARBON HIGHWAYS, BUT THE SEA IS NOT THE ONLY DESTINATION.

MANY OF MY FELLOW TERRIGENOUS MOLECULES WERE RAPIDLY BIO-DEGRADED JUST DAYS AFTER THEY ENTERED THE STREAM.

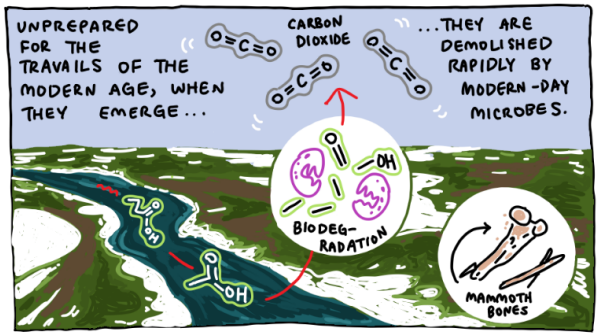
THE HUNGRY MICROBES LIVING IN RIVERINE ECOSYSTEMS DEVOUR AND REMINERALIZE A LOT OF ORGANIC CARBON...

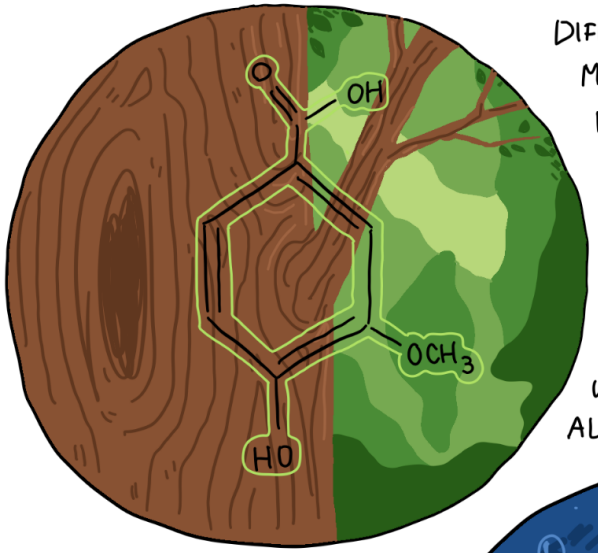
Boo!

Yipe!

... AND SUNLIGHT CAN DESTROY MOLECULES AS WELL...

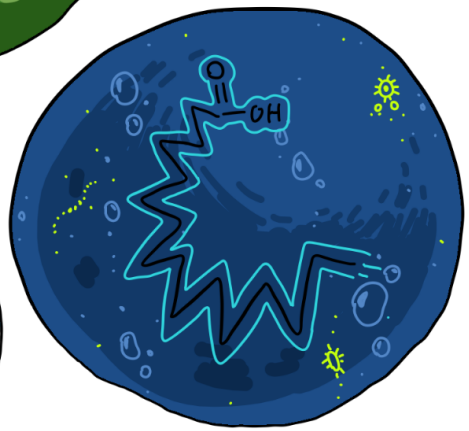
... BEFORE THEY HAVE A CHANCE TO REACH THE OCEAN.

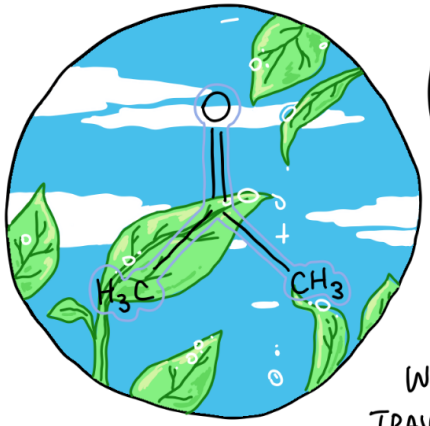




DIFFERENT KINDS OF DOC MOLECULES COME FROM DIFFERENT SOURCES AND ENVIRONMENTS.

SCIENTISTS CAN TRY TO LOOK AT US AND DETERMINE WHERE WE CAME FROM AND WHAT HAPPENED TO US ALONG THE WAY.

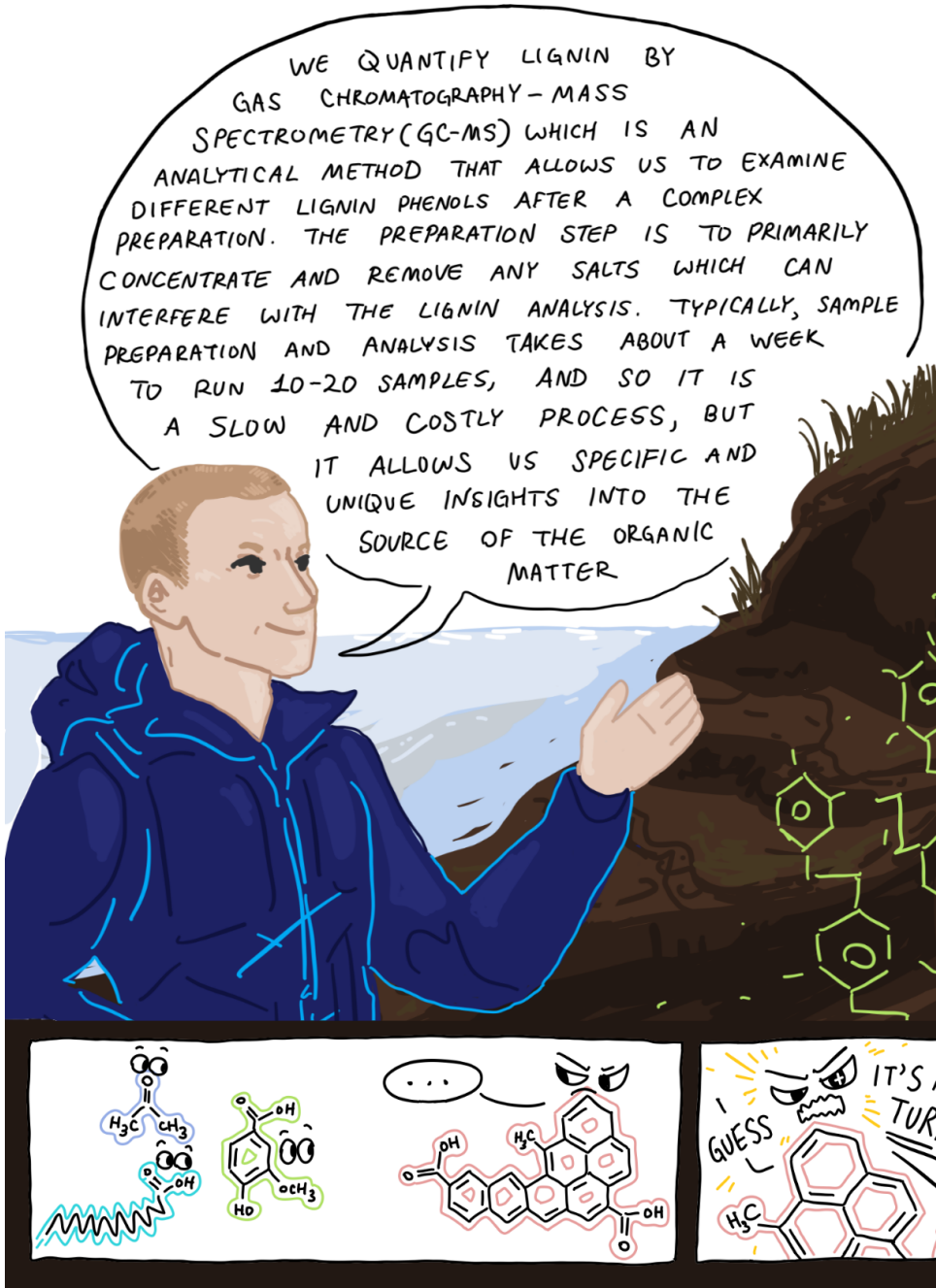




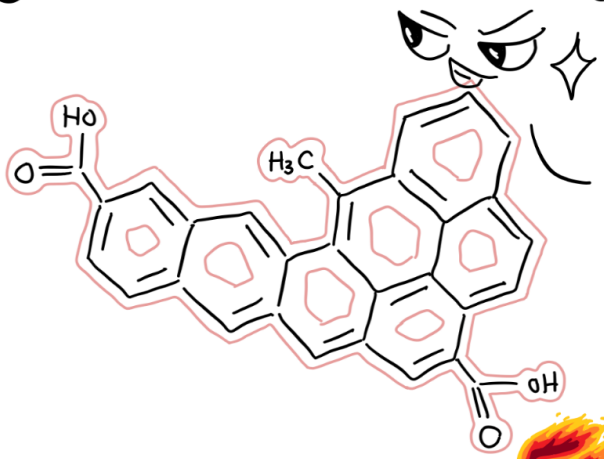
WHAT THEY LEARN FROM OUR TRAVELS HELPS THEM UNDERSTAND THE GLOBAL CARBON CYCLE...

THE SCIENTIST'S PERSPECTIVE:

DR ROB SPENCER OF FLORIDA STATE UNIVERSITY STUDIES TERRIGENOUS DOM. STUDYING THE OCCURENCE OF LIGNIN IN AQUATIC ECOSYSTEMS HELPS SCIENTISTS UNDERSTAND GLOBAL CARBON CYCLING:



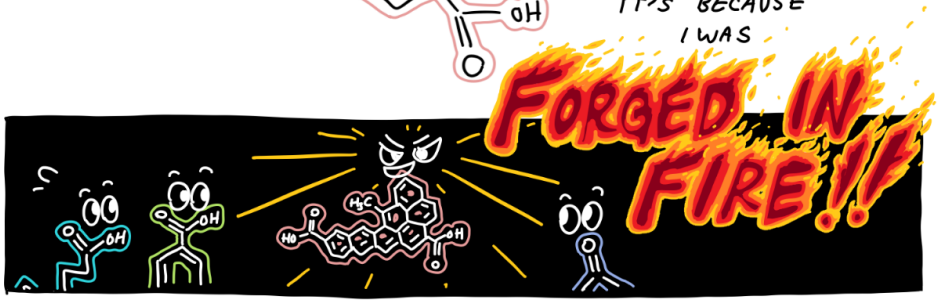
CHAPTER 4: THERMOGENIC CARBON OR BLACK CARBON

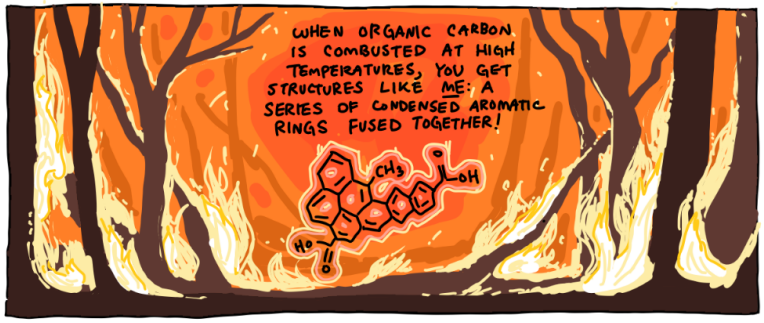


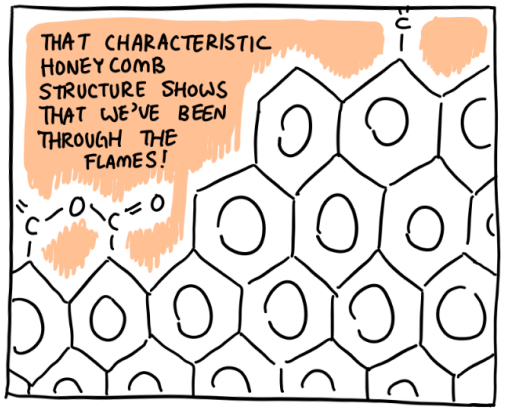
I'M BLACK CARBON, AND I'M THE AWESOMEST OF ALL ORGANIC CARBON MOLECULES!

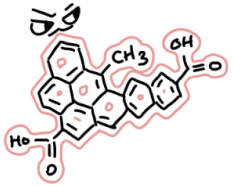
WHY, YOU ASK?

IT'S BECAUSE I WAS

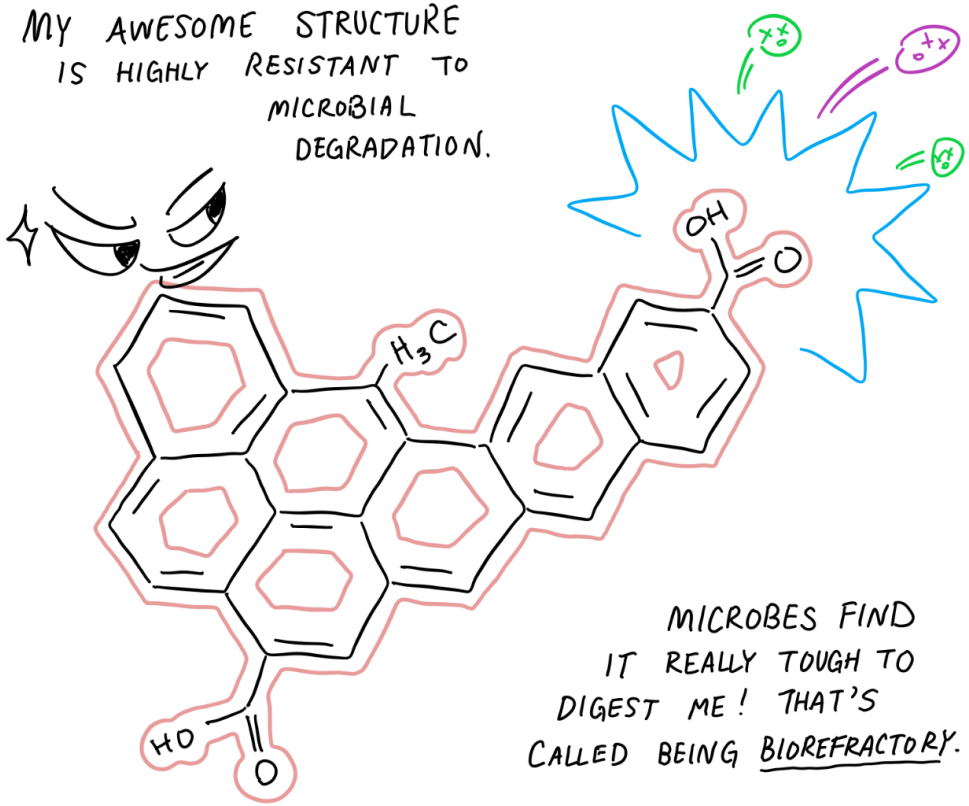




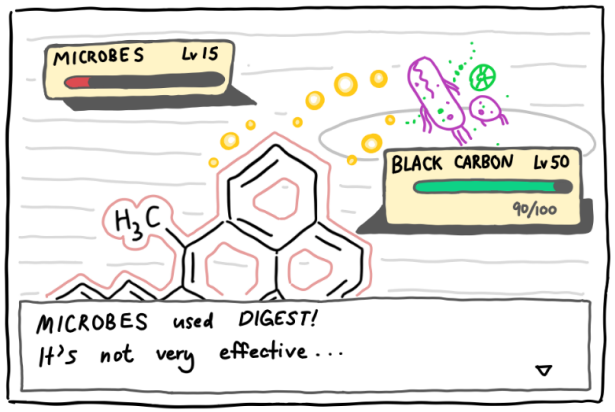


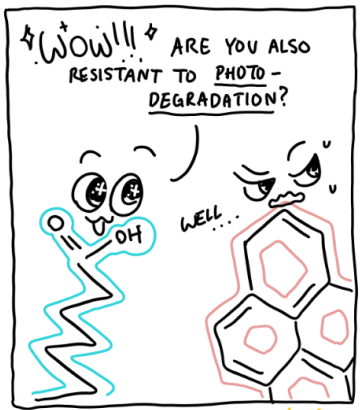


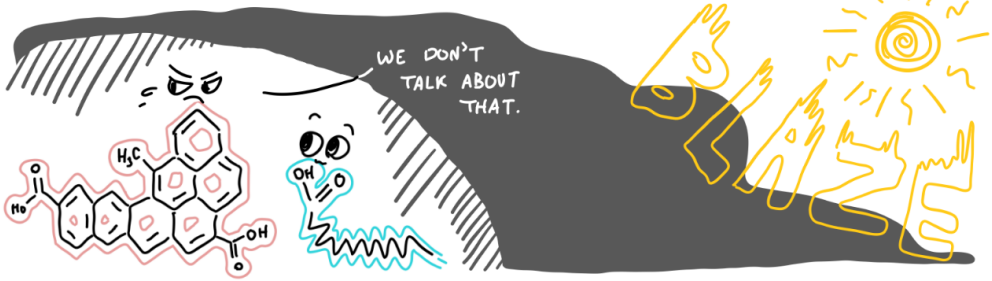
MY AWESOME STRUCTURE IS HIGHLY RESISTANT TO MICROBIAL DEGRADATION.



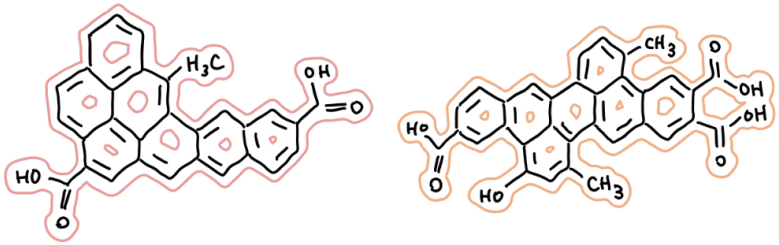
MICROBES FIND IT REALLY TOUGH TO DIGEST ME! THAT'S CALLED BEING BIOREFRACTORY.



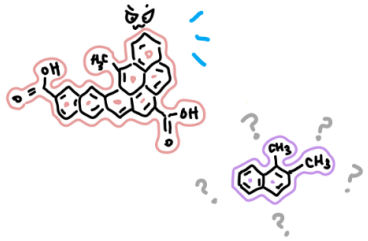




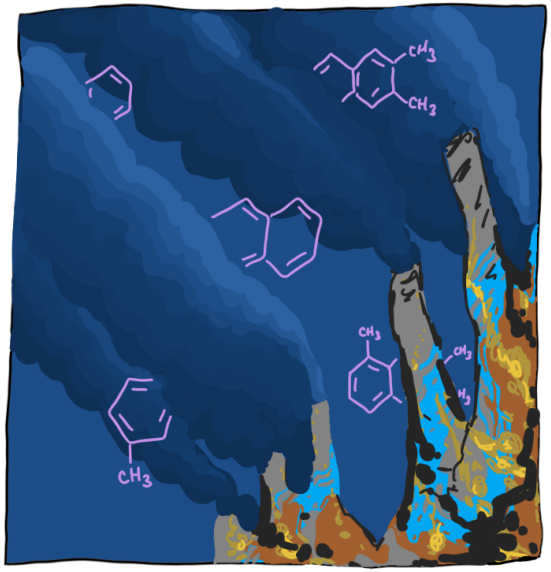
CONDENSED AROMATIC CARBON



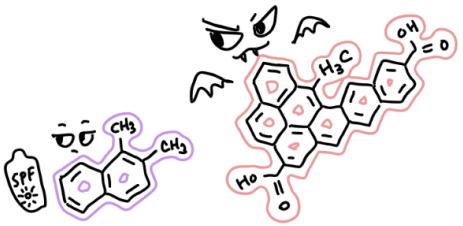
PRODUCED WHEN ORGANIC MATTER IS HEATED, IT BEARS A DISTINCTIVE STRUCTURE OF FUSED RINGS.



DOC WITH A SIMILAR STRUCTURE TO BLACK CARBON ORIGINATING IN FOREST FIRES HAS BEEN FOUND IN THE DEEP OCEAN, POSSIBLY ORIGINATING FROM HYDRO-THERMAL VENTS, AN UNDERWATER SOURCE OF POWERFUL HEAT.



BLACK CARBON IS RESISTANT TO BIODEGRADATION, BUT CAN BE DEGRADED BY SUNLIGHT.



SMOKE PLUMES CARRY ASH AND PARTICULATE ORGANIC CARBON FAR FROM THE ORIGINAL SOURCE.

INTENSE HEAT FORMS CONDENSED AROMATICS!

BLACK CARBON IS PRODUCED IN FOREST FIRE EVENTS AND TRAVELS DOWNSLOPE.

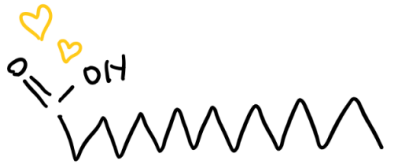
BLACK CARBON DEPOSITED IN THE LANDSCAPE IS HIGHLY RESISTANT TO DEGRADATION AND MAY PERSIST FOR MILLENIA, OFTEN MAKING IT THE OLDEST CARBON IN TERRESTRIAL SOILS.

CHARCOAL

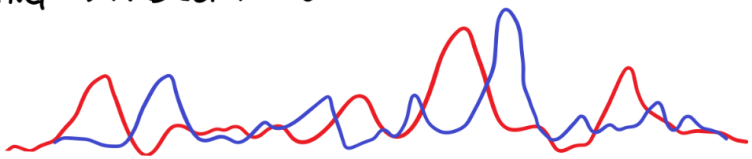
CHARCOAL IS ERODED INTO RIVER SYSTEMS, WHERE IT IS SWIFTLY CARRIED TO NEW LOCATIONS, INCLUDING EVENTUALLY — THE OCEAN!

THE SCIENTIST'S PERSPECTIVE:

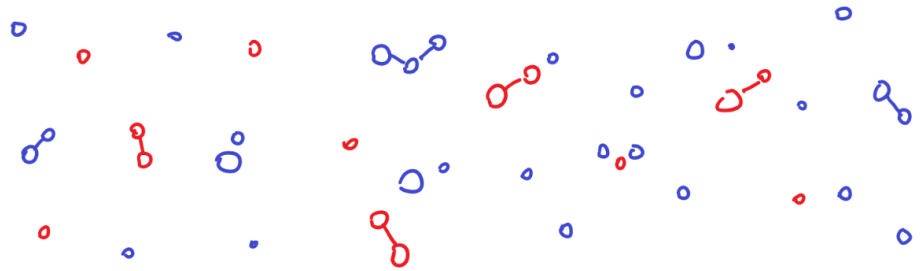
BLACK CARBON, PRODUCED FROM THE COMBUSTION OF BIOMASS, IS AN EXCITING AND OFTEN MYSTERIOUS SUBFIELD OF CARBON RESEARCH. SASHA WAGNER, A PROFESSOR AT RENSSELAER POLYTECHNIC INSTITUTE IN TROY, NY, STUDIES BLACK CARBON AND HOW IT BEHAVES IN AQUATIC ENVIRONMENTS.



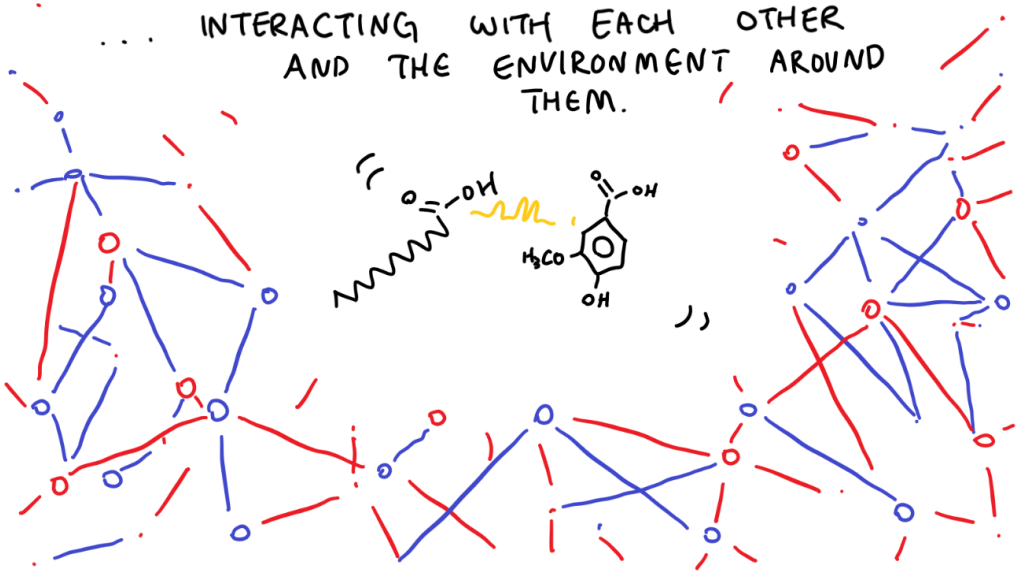
ALTHOUGH INDIVIDUAL MOLECULES (OR GROUPS OF MOLECULES) CAN BE ISOLATED AND CHARACTERIZED USING DIFFERENT SCIENTIFIC TECHNIQUES...



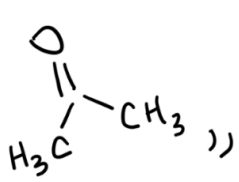
...IN THE OCEAN, DOM EXISTS AS A MASSIVE, HETEROGENEOUS POOL OF THOUSANDS—EVEN MILLIONS— OF COEXISTING MOLECULES.



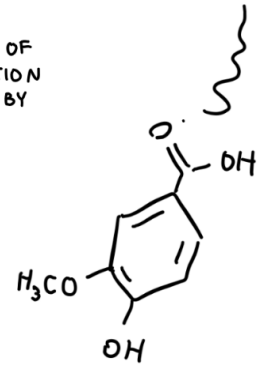
...INTERACTING WITH EACH OTHER AND THE ENVIRONMENT AROUND THEM.



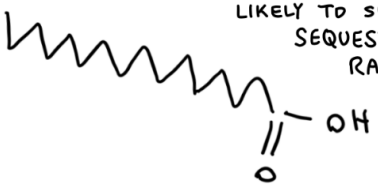
THE DEEP-OCEAN POOL CONTAINS A SELECT GROUP OF ENVIRONMENTAL MOLECULES THAT ENDURED PROCESSING BOTH ON THE WAY TO THE OCEAN AND WITHIN IT.

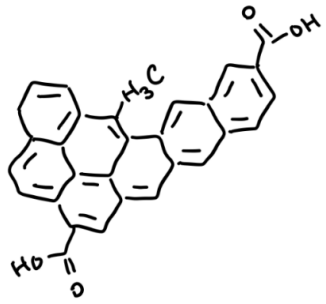


THESE "REFRACTORY" MOLECULES HAVE ESCAPED THE FATE OF REMINERALIZATION AND DEGRADATION BY MICROBES, AND BREAKDOWN BY SUNLIGHT.



ONE QUESTION SCIENTISTS GRAPPLE WITH TODAY: WHAT MAKES DOC MORE LIKELY TO SURVIVE, AND BECOME SEQUESTERED, WHILE OTHER DOC RAPIDLY REMINERALIZES?





SAID ANOTHER WAY: WHAT MAKES DOC REFRACTORY?

OCEANIC DOC IS SO COMPLEX, AND SO VAST, THAT TRYING TO CHARACTERIZE EVERY INDIVIDUAL MOLECULE IS LIKE COUNTING GRAINS OF SAND ON AN ENORMOUS BEACH.

BUT THIS IS WHAT MAKES THE STUDY OF DOM SO CAPTIVATING — LURKING IN THAT VAST DIVERSITY OF MOLECULES ARE UNKNOWN CHEMISTRIES WE HAVE YET TO REVEAL... OR MAY NEVER BE ABLE TO FULLY FATHOM.

ONE OF THE GREAT MYSTERIES OF OUR PLANET, THE TALES OF TERRESTRIAL AND OCEANIC DOM MOLECULES CAN BE READ AND UNDERSTOOD BY RIGOROUSLY DEVELOPED TECHNOLOGIES AND METHODS, WIELDED BY SCIENTISTS.

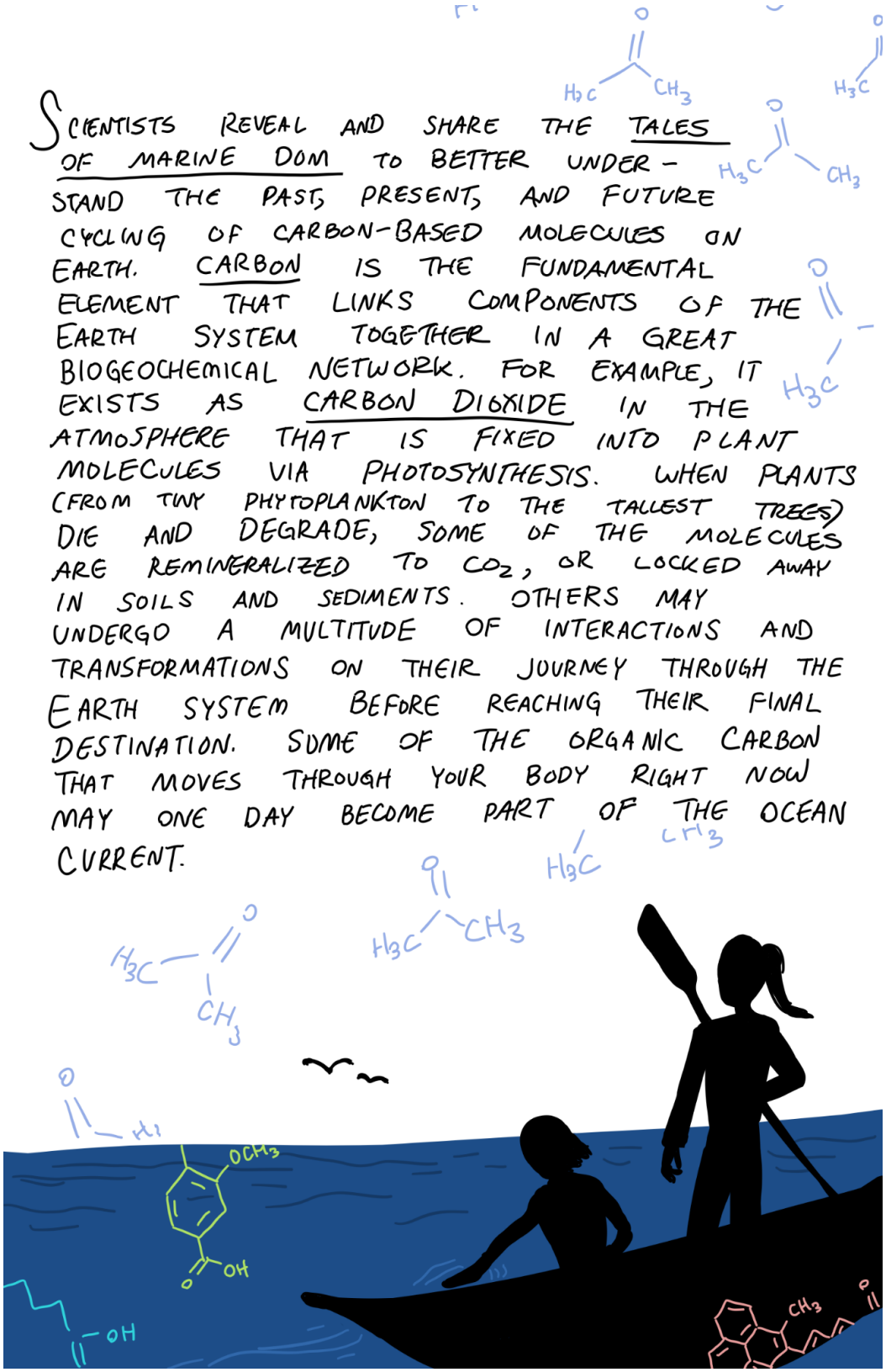
BY ANALYZING DATA IN ENVIRONMENTAL CONTEXT,

WE PRISE OUT INDIVIDUAL SLICES OF THE TRUTH, CAPTURED IN SPACE AND TIME.

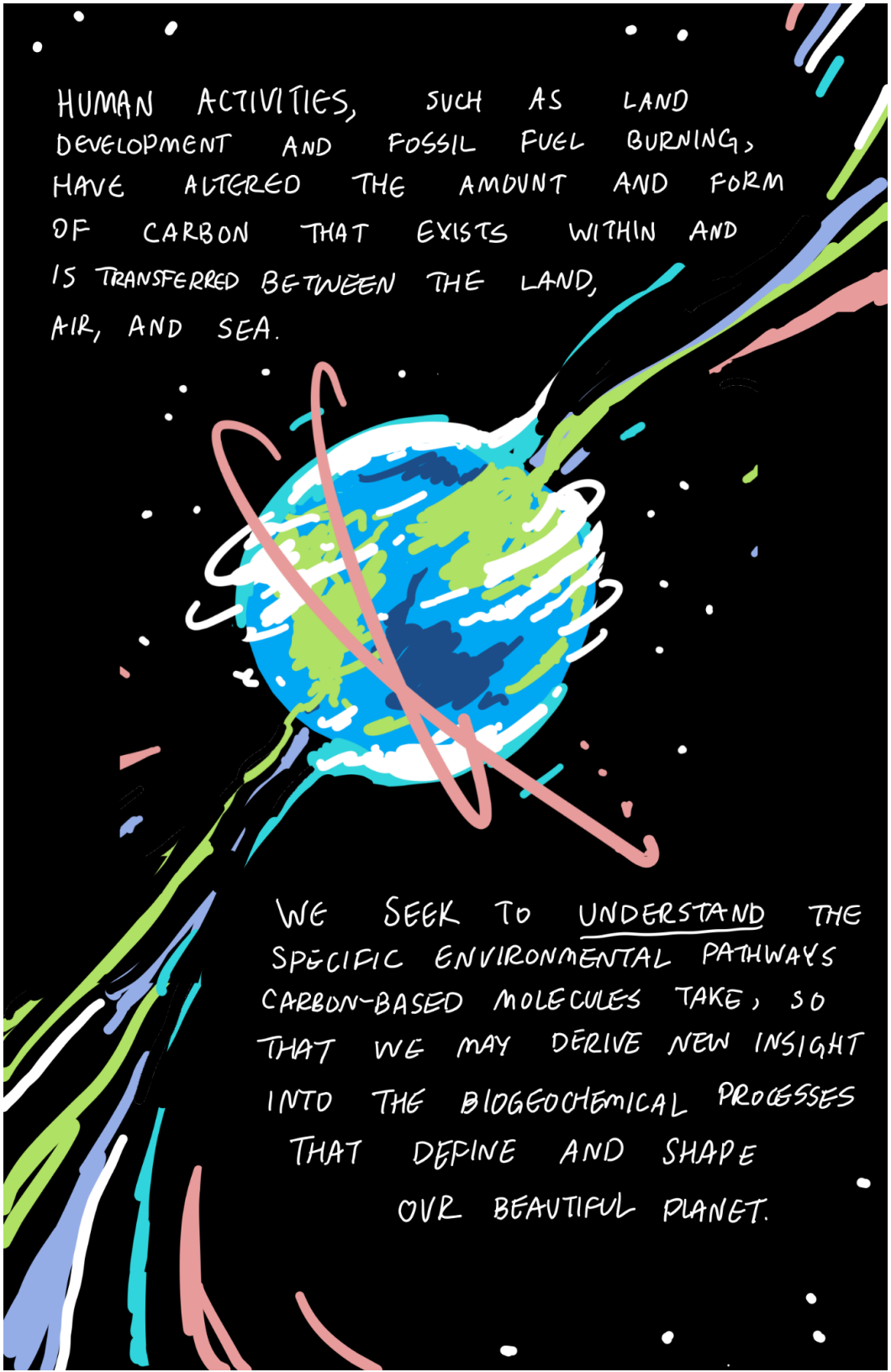
GRAPHS AND COMPUTER PROGRAMS CAN PARSE MEANING OUT OF NUMBERS THAT DIFFER BY ORDERS OF MAGNITUDE OR ARE AS SMALL AS THE DIFFERENCE BETWEEN TWO ISOTOPES OF THE SAME ELEMENT.

HOWEVER, INDIVIDUAL SCIENTIFIC METHODS DO NOT REVEAL EVERYTHING, AND USING THEM IS LIKE SHINING A FLASHLIGHT INTO A DARK ROOM: WHEN ONE AREA IS ILLUMINATED, OTHER AREAS REMAIN IN SHADOW.

SCIENTISTS REVEAL AND SHARE THE TALES OF MARINE DOM TO BETTER UNDERSTAND THE PAST, PRESENT, AND FUTURE CYCLING OF CARBON-BASED MOLECULES ON EARTH. CARBON IS THE FUNDAMENTAL ELEMENT THAT LINKS COMPONENTS OF THE EARTH SYSTEM TOGETHER IN A GREAT BIOGEOCHEMICAL NETWORK. FOR EXAMPLE, IT EXISTS AS CARBON DIOXIDE IN THE ATMOSPHERE THAT IS FIXED INTO PLANT MOLECULES VIA PHOTOSYNTHESIS. WHEN PLANTS (FROM TINY PHYTOPLANKTON TO THE TALLEST TREES) DIE AND DEGRADE, SOME OF THE MOLECULES ARE REMINERALIZED TO CO_2, OR LOCKED AWAY IN SOILS AND SEDIMENTS. OTHERS MAY UNDERGO A MULTITUDE OF INTERACTIONS AND TRANSFORMATIONS ON THEIR JOURNEY THROUGH THE EARTH SYSTEM BEFORE REACHING THEIR FINAL DESTINATION. SOME OF THE ORGANIC CARBON THAT MOVES THROUGH YOUR BODY RIGHT NOW MAY ONE DAY BECOME PART OF THE OCEAN CURRENT.



HUMAN ACTIVITIES, SUCH AS LAND DEVELOPMENT AND FOSSIL FUEL BURNING, HAVE ALTERED THE AMOUNT AND FORM OF CARBON THAT EXISTS WITHIN AND IS TRANSFERRED BETWEEN THE LAND, AIR, AND SEA.



WE SEEK TO UNDERSTAND THE SPECIFIC ENVIRONMENTAL PATHWAYS CARBON-BASED MOLECULES TAKE, SO THAT WE MAY DERIVE NEW INSIGHT INTO THE BIOGEOCHEMICAL PROCESSES THAT DEFINE AND SHAPE OUR BEAUTIFUL PLANET.

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AS PART OF RPI'S ARCH PROGRAM

FURTHER READING: THIS ZINE WAS INSPIRED BY THE PEER-REVIEWED PAPER "SOOTHSAYING DOM: A CURRENT PERSPECTIVE ON THE FUTURE OF OCEANIC DISSOLVED ORGANIC CARBON" ORIGINALLY PUBLISHED IN *FRONTIERS IN MARINE SCIENCE*.

WE THANK THE FOLLOWING FOR CONTRIBUTING THEIR SCIENTIFIC PERSPECTIVES TO THIS ZINE:

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TO READ MORE ABOUT MARINE DOM BIOGEOCHEMISTRY AND SUBJECTS MENTIONED IN SCIENTIST PERSPECTIVES,

SCAN HERE!

OR VISIT:
BIT.LY/3A00yfi

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