WE'RE IN THIS MATTER FOR ALL ORGANISMS TO GROW FROM MICROSCOPIC ATOMS TO GIANT SEQUOIA TREES. THEY ARE ACTUALLY MADE OF ATOMS AND MOLECULES, FROM MICROSCOPIC BACTERIA TO GIANT SEQUOIA TREES, ALL ORGANISMS NEED MATTER FOR LIFE.

IN THIS, OUR LAST SESSION, WE ARE GOING TO LOOK AT ATOMS AND MOLECULES THAT ARE ESSENTIAL TO LIFE. WE WILL TRACE THE FLOW OF MATERIALS AMONG ORGANISMS AND THEIR ENVIRONMENTS. WHEN WE STUDY THE INTERACTIONS BETWEEN ORGANISMS AND THE EXCHANGE OF MATERIALS BETWEEN ORGANISMS AND THE PHYSICAL ENVIRONMENT, WE ARE LOOKING AT HOW ECOSYSTEMS FUNCTION. AS WE LEARN ABOUT MATTER AND ECOSYSTEMS, WE'LL TIE TOGETHER THE EXTREMES OF LIFE'S ORGANIZATIONAL LEVELS, FROM THE SMALLEST BUILDING BLOCKS, ATOMS AND MOLECULES, TO ECOSYSTEMS, COMMUNITIES OF ORGANISMS CO-EXISTING AND INTERACTING WITH EACH OTHER AND THE PHYSICAL ENVIRONMENT.

Zook: WE'LL START OUT BY ASKING SOME GENERAL QUESTIONS ABOUT MATTER AND LIFE. THEN WE'LL LOOK AT HOW MATERIALS ARE ACQUIRED AND USED AS THEY MOVE THROUGH LINKS IN FOOD CHAINS, FROM PRODUCERS TO CONSUMERS TO DECOMPOSERS.

Grisham: OUR INVESTIGATION WILL LEAD US TO ASK SOME CHALLENGING QUESTIONS LIKE... THESE QUESTIONS ARE PART OF LESSON PLANS DEVELOPED BY DR. TINA GROTZER AT HARVARD UNIVERSITY'S PROJECT ZERO.

Grotzer: WE WERE LOOKING AT THE KINDS OF MISUNDERSTANDINGS THAT KIDS HAD WHEN THEY WERE TRYING TO LEARN SCIENCE CONCEPTS IN SCHOOL. ON THE TOPIC OF MATERIAL CYCLING, WE FOUND THAT STUDENTS OFTEN THOUGHT THAT THINGS DIDN'T DECAY OR THAT THEY DEPENDED ON UNRELIABLE KINDS OF PROCESSES TO DECAY. SO FOR EXAMPLE, A HUMAN BEING WOULD HAVE TO COME AND WALK ON THE LEAVES. OR, YOU KNOW, AN ANIMAL MIGHT HAPPEN BY, LIGHTNING MIGHT STRIKE, AND THAT THAT WAS RESPONSIBLE FOR DECAY.

SO WE STARTED TO THEN SAY, OKAY, YOU KNOW, HOW DO WE GET KIDS TO UNDERSTAND THAT FOR ALL THE DECAY THAT TAKES PLACE IN THE WORLD, YOU NEED TO HAVE A MORE DEPENDABLE PROCESS. THAT SOMETHING ELSE MUST BE GOING ON SINCE THOSE THINGS DON'T HAPPEN REGULARLY?

Child: HOW MUCH WAS THIS?

Child: IT'S FOUR RED, FOUR RED, WHERE ARE THE GUMMY WORMS?
bernstein: okay.
then the worms might just, even if some of that organic material turned to mold, you think the worms might eat it. yeah.
anybody have a different idea about that? kelly.
all the organic stuff will be gone. in which tank, kelly? in both tanks. in both tanks. because the worm tank is -- has the worms that will break it down. and in the tank that doesn't have the worms, it will just break, it will come down into, um, mold.
mary ann bernstein used the terms "organic" and "inorganic" to describe the contents of the tank earlier in this course, we talked about this distinction, which can be confusing, especially with the popularity of organic food and organic farming. in a scientific sense, all farming would be considered organic because the term is used to describe the molecules that life is made of, carbon-based matter. all of the food in the tanks is organic -- the froot loops, bread, and gummy worms -- because they're derived from living matter. "inorganic" is used to describe the nonliving world around us, such as the chemical components of the environment. the sand, the tanks themselves, and water are examples of inorganic matter used in this lesson.
zook: over a lifetime, an organism builds up its physical body. and those atoms have to come from somewhere. but where? we asked the children in the science studio, where do living things get their matter?
abrams: so then where did those molecules come from? well, they came from -- the energy created the molecules inside it. yeah.
so can energy create matter? yeah, basically.
narrator: the relationship between matter and energy continues to be a source of confusion, just as we saw in session seven.
PI AND MICHAEL CORRECTLY BELIEVE THAT MATTER AND ENERGY ARE ESSENTIAL TO GROWTH, AND WE KNOW THAT ENERGY IS PACKAGED IN THE FORM OF FOOD. BUT MATTER DOESN'T COME FROM ENERGY.

A SIMPLIFIED WAY OF SEPARATING THESE IDEAS IS TO THINK OF ENERGY AS THE FUEL OF LIFE AND MATTER AS THE BUILDING BLOCK OF LIFE.

Woman: IN THIS FOOD CHAIN, YOU KNOW, ONE THING'S GETTING EATEN BY THE OTHER, GETTING EATEN BY THE OTHER.

WHAT'S GETTING PASSED FROM THING TO THING? FOOD. AND WHAT'S IN THE FOOD? NUTRIENTS. YEAH, NUTRIENTS. THAT HELPS THEM GROW. YEAH, IT HELPS THEM GROW AND MAKE THEM BIGGER.

WELL, I GUESS THIS FISH COULD BECOME AS BIG AS THE BIG FISH. IT'S A, UM -- MAGGY?

[MAGGY LAUGHING ] UM, IT'S LIKE KIND OF LIKE A VITAMIN. NOT LIKE THE VITAMINS YOU EAT, BUT LIKE THE VITAMIN LIKE VITAMIN A AND VITAMIN B, I THINK.

IT'S KIND OF LIKE THAT. IT'S NOT THAT, IT'S NOT THAT, BUT IT'S LIKE IT, I THINK.

I DON'T KNOW.

Narrator: MAGGY LINKS NUTRIENTS TO VITAMINS AND SHE ISN'T TOO FAR OFF. BOTH ARE MATERIALS ESSENTIAL TO LIFE. BUT HOW DOES THE LITTLE FISH BECOME A BIG FISH? WHERE DOES THE MATTER IMPORTANT TO LIFE COME FROM?

IN THINKING ABOUT THIS QUESTION, IT CAN BE HELPFUL TO THINK ABOUT MATTER IN TERMS OF ITS BASIC CONSTITUENTS -- ELEMENTS.

ELEMENTS ARE PARTICULAR TYPES OF ATOMS. AND THERE ARE OVER 100 ELEMENTS ON EARTH. AND YET EIGHT MAKE UP 99% OF THE BODIES OF ALL ORGANISMS.

Zook: THESE EIGHT ELEMENTS ARE THE INGREDIENTS OF WHAT WE CALL "SPONCH CaFe," A MNEMONIC THAT HELPS KEEP TRACK OF LIFE'S ESSENTIAL ELEMENTS -- Grisham: CALCIUM AND IRON ARE ESSENTIAL ELEMENTS FOUND IN SMALLER AMOUNTS AND REPRESENTED BY "CaFe," THE ATOMIC SYMBOLS FOR CALCIUM AND IRON.

ALL ORGANISMS -- FROGS, FLOWERS, EVEN MOLD AND BACTERIA -- ARE BUILT FROM COMBINATIONS OF THESE ELEMENTS, BUT HOW DO MATERIALS LIKE THESE CONTRIBUTE TO GROWTH?

NOW, WHEN WE ARE LOOKING AT THIS PLANT, AND THIS PLANT STARTED OFF TO BE A LITTLE SEED, HOW DID IT TURN INTO THIS BIG PLANT WITH FLOWERS? IT GREW USING SUNLIGHT AND FOOD.

AND NUTRIENTS. YEAH.

Abrams: AND ARE ALL OF THOSE THINGS NUTRIENTS? YEAH.

WELL, I MEAN, LIKE, FOOD IS MATTER AND IT CAN BUILD YOU UP. WHEN YOU GROW, YOU HAVE MORE ATOMS IN YOUR BODY AS YOU GROW.

BUT ATOMS KIND OF ARE JUST THERE AND THEY ADD WHEN THEY NEED TO. THEY DON'T DO ANYTHING. THEY DON'T STOP YOU FROM DOING ANYTHING, THEY'RE JUST THERE. AND WHEN YOU GROW, THEY KIND OF, THEY GET -- THERE'S MORE ATOMS IN YOUR BODY.

GREG AND MAGGY HAVE A SENSE THAT MATTER ACCUMulates. BUT THEY ALSO SUGGEST THAT ATOMS CAN REPRODUCE THEMSELVES.

IS THAT TRUE?

CAN MATTER BE CREATED OUT OF NOTHING?

ONE OF THE BIG IDEAS IN SCIENCE IS THE PRINCIPLE OF CONSERVATION OF MATTER. SCIENTISTS HAVE OBSERVED OVER AND OVER AGAIN THAT, EXCEPT IN VERY SPECIAL CIRCUMSTANCES, MATTER CAN'T BE CREATED OR DESTROYED.

IF YOU SEE MATTER ACCUMULATING SOMEWHERE, IT HAS TO HAVE BEEN TRANSFERRED FROM SOMEWHERE ELSE.

THIS MEANS THAT ATOMS CAN'T REPRODUCE, AS THE CHILDREN SUGGEST.

NEARLY ALL THE MATTER ON OUR PLANET TODAY HAS BEEN HERE FOR THE PAST 4.5 BILLION YEARS.

THERE IS A FINITE AMOUNT OF MATTER ON EARTH. AND IT MOVES FROM ONE PLACE TO ANOTHER, RECOMBINING IN DIFFERENT WAYS.

WHILE ALL OF THE ELEMENTS OF THE SPONCH CaFe ARE ESSENTIAL BUILDING BLOCKS OF LIFE, IN THIS PROGRAM WE WERE FOCUSING ON CARBON AND NITROGEN BECAUSE THEY ARE REPRESENTATIVE EXAMPLES, WHERE DO WE FIND THE ELEMENTS ESSENTIAL TO LIFE?
WE PUT THIS QUESTION TO
DR. ADRIEN FINZI,
AN ECOLOGIST AND COLLEAGUE OF MINE HERE
AT BOSTON UNIVERSITY.
THERE ARE MANY ELEMENTS THAT ARE
IMPORTANT TO LIFE ON LAND,
BUT CARBON, NITROGEN,
AND PHOSPHORUS ARE AMONG
THE MOST IMPORTANT
FOR TERRESTRIAL ECOSYSTEMS,
LIKE THE FOREST
THAT YOU SEE HERE.
THESE ELEMENTS CAN BE FOUND
IN THE ATMOSPHERE,
IN THE PLANTS THEMSELVES,
AND ALSO IN SOILS.
NITROGEN AND PHOSPHOROUS ARE ALSO KEY
ELEMENTS IN LIFE.
AND THEY EXIST IN VERY LOW QUANTITIES IN
SOILS,
WHICH MAKES THEM A VERY PRECIOUS
RESOURCE FOR PLANT GROWTH.
PLANTS HAVE ADAPTED THEMSELVES
TO DEALING WITH THIS LOW AVAILABILITY
OF THESE KEY ESSENTIAL ELEMENTS.
ONE OF THE MOST
DRAMATIC EXAMPLES
IS THE RESORPTION
OF THESE NUTRIENTS,
THAT IS, THE REMOVAL OF
THE NUTRIENTS FROM THE LEAVES
IN THE AUTUMN.
YOU SEE THIS BRIGHTLY COLORED FOLIAGE IN
THE BACK.
THIS IS AN INDICATION THAT PLANTS ARE
ACTIVELY WITHDRAWING
NITROGEN AND PHOSPHOROUS
FROM THE LEAVES
BEFORE THOSE LEAVES DIE.
THE CARBON THAT
ENTERS INTO PLANTS
THROUGH THE PROCESS OF PHOTOSYNTHESIS
CAN BE STORED IN
MANY DIFFERENT PLACES.
AND ONE OF THE MOST
IMPORTANT STORAGES
IS IN
THE PRODUCTION OF WOOD.
THE CONTENT OF WOOD IS
ABOUT 50% CARBON.
SO THAT WHEN YOU'RE LOOKING AT THE STEM
OF A TREE,
YOU CAN ESTIMATE THAT 50%
OF THE MASS OF THAT STRUCTURE
IS CARBON ALONE.
TO FIND OUT HOW
ELEMENTS LIKE CARBON
ENTER THE FOOD CHAIN,
LET'S START WITH
THE FIRST LINK,
THE PRODUCERS.
WHERE DO THEY GET
THE CARBON THEY NEED?
Zook: WHEN WE LOOK AT PHOTOSYNTHESIS,
WE SEE THAT PLANTS TAKE CARBON DIOXIDE
FROM THE AIR
AND CONVERT IT TO SUGARS.
IN THIS PROCESS, THE CARBON
IN CARBON DIOXIDE IS FIXED,
WHICH MEANS IT'S USED TO BUILD SUGAR
MOLECULES
 THAT THE PLANT CAN
THEN USE FOR FOOD.
Grisham: ACQUIRING CARBON
IS A DIRECT PROCESS FOR PLANTS,
BUT ELEMENTS LIKE NITROGEN CAN BE MORE
DIFFICULT
AS WE FOUND OUT
FROM DR. NICKY SHEATS,
A POST-DOCTORAL FELLOW
AT COLUMBIA UNIVERSITY'S
EARTH INSTITUTE.
WE NEED NITROGEN FOR LIFE,
ALL FORMS OF LIFE
THAT WE KNOW.
AND IN MANY CASES, NITROGEN
IS THE LIMITING FACTOR
WHICH MEANS THERE'S NOT ENOUGH
NITROGEN TO GO AROUND.
YOU'VE MORE LIFE,
MORE ABUNDANCE OF LIFE.
IF YOU HAVE MORE NITROGEN
AND THE KIND OF IRONY OF THIS IS
THAT THERE IS A LARGE POOL
OF NITROGEN ALL AROUND US
IN THE AIR.
THE ATMOSPHERE IS 78% NITROGEN.
THE PROBLEM IS, IT'S NOT IN
THE FORM THAT LIFE CAN USE.
AND TO GET INTO THAT FORM
IS DIFFICULT.
AND ONLY CERTAIN BACTERIA
CAN ACTUALLY TAKE THE NITROGEN FROM
THE AIR
AND PUT IT IN A FORM
THAT LIFE CAN USE.
WE CALL IT
MAKING IT "BIO-AVAILABLE."
THEN THAT NITROGEN CAN BE
USED BY OTHER LIFE
AND IT'S IN THE FOOD WEB.
WE CALL IT
"NITROGEN FIXATION."
THESE BACTERIA FIX THE NITROGEN.
Narrator: MANY SPECIES OF NITROGEN-FIXING
BACTERIA
IN THE SOIL DO THIS.
ANOTHER EXAMPLE OF BRINGING MATTER IN A
NONLIVING FORM
INTO THE LIVING WORLD
IS SYMBIOTIC PARTNERSHIPS.
THESE CLOVER PLANTS SOLVE
THEIR NITROGEN SUPPLY NEEDS
BY JOINING FORCES WITH NITROGEN-FIXING
BACTERIA.
CLOVER, ALONG WITH MANY MEMBERS OF THE
LEGUME FAMILY,
HAVE DEVELOPED ROOT NODULES
THAT HOUSE NITROGEN-FIXING BACTERIA.
LET'S TAKE A CLOSER LOOK.
IN ONE OF THE EXAMPLES,
WE'VE REMOVED THE SOIL
SO THAT WE CAN MORE EASILY
SEE THE ROOTS.
AND WE HAVE A SIMPLE
MAGNIFYING GLASS HERE
THAT WE CAN
TAKE A CLOSER LOOK.
AND THEY'RE CERTAINLY THERE.
THEY'RE SMALL.
THESE NODULES ARE
THROUGHOUT THE ROOTS.
AND THE RELATIONSHIP IS SYMBIOTIC
BECAUSE THE TWO ORGANISMS DEVELOP A
NEW STRUCTURE --
IN THIS CASE THE NODULES --
THAT ALLOW FOR THE EXCHANGE
OF MATERIALS.
THE BACTERIA RECEIVES SUGAR
FROM THE PLANT
AND TRANSFER NITROGEN TO IT.
NOW, THERE ARE ALSO
EXTREME STRATEGIES
FOR OBTAINING
ESSENTIAL ELEMENTS.
LETS SEE HOW THE PITCHER PLANTS DR.
AARON ELLISON STUDIES
GET THE ELEMENTS THAT THEY NEED.
Ellison: THE PITCHER PLANTS ARE
CARNIVOROUS PLANTS.
AND THEY GET THEIR NUTRIENTS
BY CATCHING INSECTS.
WHEREAS MOST OTHER PLANTS
ARE GETTING THEIR NUTRIENTS
OUT OF THE SOIL.
AND THE NUTRIENTS --
SUCH IMPORTANT NUTRIENTS
SUCH AS NITROGEN AND PHOSPHOROUS AND
POTASSIUM --
ARE ACTUALLY USED TO MAKE
THE ENZYMES
THAT ARE INVOLVED IN PHOTOSYNTHESIS.
THE PLANT MAKES NECTAR AROUND THE EDGE
OF THE MOUTH
IN ORDER TO ATTRACT THE INSECTS TO COME
INTO THE PLANTS.
SO THE WASP HERE IS WALKING
AROUND THE LIP.
COLLECTING NECTAR
OFF THE PLANT.
AND SOMETIMES THE INSECT WILL GET
CONFUSED BY THE LIGHT
AND WILL CONTINUE TO WALK DOWN INTO
THE TUBE.
AND THEN IT WON'T BE ABLE
TO GET BACK OUT.
AND THEN THEY ARE DECOMPOSED
BY THE BACTERIA AND PROTOZOA
AND ROTIFIERS AND MITES THAT LIVE INSIDE
OF THE PITCHER,
AS WELL AS BY DIGESTIVE ENZYMES
THAT THE PITCHER
ITSELF PRODUCES.
IT TAKES FOUR TO SIX DAYS FOR
AN INSECT THAT'S CAPTURED
TO BE BROKEN DOWN AND ITS NUTRIENTS
RELEASED TO THE PLANT.
Grisham: ONE DIFFERENCE BETWEEN A PITCHER
PLANT
AND A FOREST PLANT
IS THAT PITCHER PLANTS
HAVE THEIR DECOMPOSERS
IN THEIR LEAVES.
FOREST AND LAWN PLANTS HAVE THEIR
DECOMPOSERS IN THE SOIL.
Narrator: ONE OF THE WAYS HUMANS HAVE
SOLVED THE PROBLEM
OF OBTAINING NITROGEN WAS DEVELOPED BY
FRITZ HABER,
A GERMAN CHEMIST.
IN 1908, HE PERFECTED
A RELIABLE WAY
OF USING NITROGEN FROM THE AIR
TO MAKE AGRICULTURAL FERTILIZERS.
IF YOU'RE A FARMER,
YOU NEED A LOT OF NITROGEN.
WE ALL KNOW NOW WHAT WE DO IS
WE HAVE FERTILIZER.
FERTILIZER IS ACTUALLY MORE INTERESTING
THAN IT MAY SEEM,
BECAUSE WE HAVE LEARNED INDUSTRIALLY
HOW TO DO
WHAT THE BACTERIA DO,
HOW TO FIX NITROGEN.
AND THEREFORE,
WE CAN TAKE THE NITROGEN,
MAKE FERTILIZER
AND PUT IT ON THE FIELDS.
AND NITROGEN IS NO LONGER
A LIMITING FACTOR.
Narrator: WHAT IS THE IMPACT OF HABER'S
DISCOVERY?
THIS FERTILIZER PLANT IS
A REPRESENTATIVE EXAMPLE.
IT CAPTURES 100 MILLION TONS
OF NITROGEN
FROM THE AIR EACH YEAR,
ENOUGH FIXED NITROGEN TO FEED
5 MILLION ACRES OF CORN.
MANMADE FERTILIZERS SUPPLEMENT THE
NATURAL FLOW OF MATERIALS,
ALLOWING FARMERS
TO PRODUCE MORE FOOD.
BY SOME ESTIMATES, AS MUCH AS 2/5 OF THE
WORLD'S POPULATION
ARE FED BY CROPS GROWN WITH THESE
MANMADE FERTILIZERS.
WE'LL LOOK AT THE EFFECTS OF THIS BOON ON
ECOSYSTEMS
LATER IN THE PROGRAM.
WE HAVE SEEN HOW CARBON
AND NITROGEN
ARE ESSENTIAL TO PHOTOSYNTHESIS AND
PLANT GROWTH.
THE PRODUCERS USE
FIXED CARBON AND NITROGEN,
AND OTHER ESSENTIAL ELEMENTS FOUND IN
SOIL, WATER, AND AIR,
TO BUILD THEIR BODIES.
WHAT ABOUT THE CONSUMERS?
WHERE DO THEY FIND
THE SPONCH CAFE IN ECOSYSTEMS?
WE SAW IN SESSION SEVEN
THAT CONSUMERS MEET THEIR
ENERGY NEEDS BY EATING FOOD,
WHICH IS ENERGY STORED
IN ORGANIC MATTER.
ORGANISMS ACQUIRE MATTER CONSTANTLY,
BUT HAVE YOU EVER WONDERED WHY?
IT'S EASY TO SEE HOW
GROWTH AND REPRODUCTION
REQUIRE AN INFLUX
OF MATTER INTO BODIES
BECAUSE WE CAN ACTUALLY SEE
THE BODIES GETTING BIGGER.
BUT WHY DO ORGANISMS THAT HAVE STOPPED
GROWING AND REPRODUCING
NEED NEW MATTER?
WE ASKED DR. SHEATS TO EXPLAIN WHY
CONSUMER ORGANISMS
NEED A CONSTANT SUPPLY
OF NITROGEN.
Sheats: WE EAT THE PLANTS
AND WE TAKE IN THE NITROGEN.
AND WE USE THE NITROGEN IN MANY OF THE
SAME WAYS THE PLANTS DO.
THERE'S A LOT OF PROTEIN
IN OUR BODY.
AND NITROGEN
IS ESSENTIAL IN PROTEIN.
SO THE NITROGEN THEN BECOMES THE
STRUCTURAL PART OF YOUR BODY.
AT SOME POINT, YOUR BODY WILL BREAK
DOWN PROTEINS
AND DNA AND ENZYMES.
THE NITROGEN THEN CAN BE
TOXIC TO YOUR BODY,
TOXIC TO
THE BODIES OF ANIMALS.
THEN YOU HAVE
TO GET RID OF THEM.
SO WE EAT PLANTS, INCORPORATE THE
NITROGEN INTO OUR BODY,
USE THE NITROGEN,
THEN WE BREAK IT DOWN.
AND WE EXCRETE IT OUT
OF OUR BODY.
CONSUMERS,
LIKE ALL ORGANISMS,
NEED A CONSTANT SUPPLY
OF NEW MATTER.
TO KEEP UP WITH THE MATERIAL NEEDS OF
CELL RENEWAL.
AND LIKE NITROGEN,
CARBON IS ALSO A STRUCTURAL
PART OF BODIES.
OVER TIME, THE ATOMS THAT
MAKE UP AN ORGANISM
ARE REPLACED AS ORGANIC MOLECULES ARE
BROKEN DOWN.
FOR INSTANCE, NEARLY
ALL OF THE ATOMS
IN A HUMAN BODY ARE
CONTINUOUSLY REPLACED.
CARBON DIOXIDE RELEASED INTO THE AIR AS
WHEN WE EXHALE.
AND IT IS EXPELLED FROM THE BODY IN FECES
AND URINE.
Narrator:
IF LIFE-SUSTAINING MATERIALS
LIKE CARBON AND NITROGEN LEAVE BODIES
AS WASTE MATTER,
ARE CONSUMER ORGANISMS
IN DANGER
OF CONVERTING ALL OF THE EARTH'S MATTER
INTO WASTE?
WHEN WE LOOKED
AT ENERGY LAST TIME,
WE SAW THAT IT IS CONTINUOUSLY
CONVERTED TO HEAT,
AN UNUSABLE FORM OF ENERGY,
AND THEN RADIATED
BACK INTO SPACE.
IS THE SAME TRUE FOR MATTER
OR CAN LIFE USE WASTES?
TO FIND OUT, WE PAID A VISIT
TO CHARLES TYLER,
PLANT MANAGER AT THE DEER ISLAND
SEWAGE TREATMENT FACILITY.
Tyler: THE MATERIAL THAT IS
IN THE WASTEWATER
IS WASTE FROM HUMAN USE.
SO THERE'S ALL KINDS
OF ORGANIC MATERIAL IN IT.
FOR OUR DECOMPOSING BACTERIA, THIS STUFF
IS FOOD.
IT IS SOMETHING THAT CAN BE BROKEN DOWN
BY THEM.
IT'S SOMETHING THAT CAN BE CONSUMED BY
THEM
SO THAT THEY CAN LIVE
NATURAL LIVES.
THEN DIE AND BECOME FOOD THEMSELVES
FOR OTHER BACTERIA.
WE USE DECOMPOSING BACTERIA
BECAUSE IT'S VERY COMPLICATED
TO GET DISSOLVED SOLIDS
OUT OF WASTEWATER.
OUR PROCESS DOES,
IN FACT, MIMIC NATURE.
WHAT WE HAVE DONE IS CONCENTRATED IT
AND ACCELERATED IT IN
A SMALL PLACE,
WHICH WE HAVE TO DO
BECAUSE THE CONCENTRATION
OF WASTE FROM THESE LARGE POPULATION
AREAS IS SO GREAT
THAT WE MUST DO IT
IN THAT WAY.
WE TAKE A SAMPLE FROM
OUR TREATMENT PROCESS
TO SEE WHAT KIND
OF BACTERIA WE HAVE
AND TO SEE WHAT KIND
OF SHAPE THEY'RE IN,
DO THEY GET ENOUGH OXYGEN?
WHAT KIND OF BACTERIA
DO WE HAVE THERE?
AND WHAT OTHER KINDS OF MICROORGANISMS
ARE IN THE WATER SO THAT WE CAN TELL IF,
IN FACT, IT IS
A HEALTHY DECOMPOSING
BACTERIA POPULATION
THAT WE HAVE IN THE SYSTEM.
WHAT WE LOOK FOR ARE A CERTAIN TYPE OF
INDICATOR ORGANISMS
THAT ARE ACTIVE IN THIS SLUDGE
THAT, IN FACT, PROVE TO US THAT THERE ARE
ALSO HEALTHY BACTERIA
OPERATING IN THE SLUDGE AS WELL.
THERE'S A ROTIFER.
THE ROTIFIERS ARE REALLY GOOD.
WE LIKE TO SEE A FEW OF THOSE BUT NOT TOO
MANY.
A NICE ROTIFER SHOWS THAT WE HAVE A
GOOD AGE OF SLUDGE.
IT'S A CONTINUOUS
MONITORING PROCESS.
WE NEED TO WATCH IT EVERY DAY. WE NEED TO
LOOK AT IT EVERY DAY.
AND WE NEED TO MAKE CHANGES EVERY DAY
IN ORDER TO KEEP UP
WITH WHAT'S COMING IN.
HERE'S THE FINAL PRODUCT --
BAY STATE FERTILIZER
THE OTHER PRODUCTS INCLUDE
TREATED WATER
PUMPED OUT TO SEA,
CARBON DIOXIDE,
AND NITROGEN GAS.
IT MAY SEEM
COUNTERINTUITIVE,
BUT THE TREATMENT
PLANT
IS A HIGHLY DESIGNED
ECOSYSTEM.
IN THE SETTLING POOLS,
THERE IS A STEADY FLOW
OF FOOD, KINDS
OF ORGANIC MATTER, AND ENERGY THAT
SUPPORTS
THE POPULATION OF
BACTERIAL DECOMPOSERS.
Zook: AND TO TAKE A LOOK AT
HOW THE REMAINS OF LIFE
ARE TREATED
IN MORE NATURAL SETTINGS,
LET'S RETURN TO THE WORM TANKS
IN MARY ANN BERNSTEIN'S CLASS.
THREE WEEKS HAVE PASSED
SINCE THE STUDENTS
PUT THE TANKS TOGETHER,
AND THEY'RE MONITORING THE WORK
OF DECOMPOSERS.
THINK ABOUT WHAT IT
LOOKED LIKE WHEN WE STARTED.
DO YOU NOTICE ANY CHANGES?
IN THE WORM TANK,
IT WAS QUITE OBVIOUS BY NOW
THAT SOMETHING WAS HAPPENING
TO THAT ORGANIC MATTER.
IT WAS JUST NOT THERE
ANYMORE.
OR,
IT STARTED TAKING ON A FORM
BACTERIA
JUST SO THAT WAY,
ALL OVER
BACTERIA
THERE WAS
ALL THE STUFF
WHEN YOU
COMING FROM?
SO, WHERE'S
INSTEAD
IT MIGHT,
AFTER A LONG
AND THEN,
GROW ON
CARA: MOLD
ABOUT
AH! WHAT
THERE'S
BECAUSE
CAN EAT
IN THE
BUT REALLY
I SORT OF
COURTNEY.
BERNSTEIN: OKAY,
LIKE WHEN
ON THE
LIKE ALL
BECAUSE
MUCH DIFFERENT
RACHEL: IT
RACHEL?
THAN WHEN
DOES IT
AT THIS
OKAY, LET'S
I WONDER
A CAUSE THERE
THERE'S
I SEE THE
TO MAKE
THE
WORMS
USED THIS FOR
FOOD
AND THEN TURNED THE
LEFTOVERS
BACK INTO SOME KIND OF
SOIL.
WE WANT THEM TO BE
ABLE TO MAKE THE
CONNECTION
AND TO BE ABLE TO QUESTION
AND SAY,
I KNOW THAT THE
DECOMPOSITION
IN THE WORM TANK
WAS CAUSED BY THE WORMS.
I SEE DECOMPOSITION ALSO HAPPENING IN THE
OTHER TANK.
THERE ARE NO WORMS THERE
TO MAKE THAT HAPPEN.
I SEE THE EFFECT,
THERE'S GOT TO BE
A CAUSE THERE SOMEWHERE.
I WONDER WHAT THAT IS.
OKAY, LET'S TAKE A LOOK
AT THIS ONE.
DOES IT LOOK DIFFERENT
THAN WHEN WE SET IT UP?
RACHEL?
Rachel: IT DOESN'T LOOK
MUCH DIFFERENT TO ME
BECAUSE EVERYTHING'S JUST --
LIKE ALL THE ANIMAL CRACKERS
AND THE CAPS ARE JUST ALL
ON THE TOP.
LIKE WHEN WE PUT THEM THERE.
BERNSTEIN: OKAY, WHAT ELSE?
COURTNEY.
Courtney: WELL,
I SORT OF KNOW THIS,
BUT REALLY NOTHING
IN THE WORM-FREE TIN
CAN EAT THE FOOD,
BECAUSE THERE'S LIKE NO, UM...
THERE'S NO WORMS.
AH! WHAT DO YOU THINK
ABOUT THAT?
CARA:
Cara: MOLD COULD STILL
GROW ON IT,
AND THEN,
AFTER A LONG TIME,
IT MIGHT, LIKE, EAT IT,
INSTEAD OF WORMS.
SO, WHERE'S THE MOLD
COMING FROM?
WHEN YOU PUT
ALL THE STUFF IN,
THERE WAS LIKE
BACTERIA AND GERMS
ALL OVER IT.
SO THAT WAY,
JUST A LOT MORE
BACTERIA COMES TOGETHER
AND THAT'S WHAT FORMS
THE MOLD.
SO IT'S NOT THAT
IT JUST APPEARS,
IT'S THAT IT HAS TO
COME FROM SOMEWHERE.
AH! EXACTLY.
LADIES AND GENTLEMEN,
IN THE WORM-FREE TANK,
WE STILL HAVE SOME
DECOMPOSERS,
AND THOSE ARE
THE VERY TINY
LITTLE ORGANISMS
THAT WE CALL
MICROBES.
BERNSTEIN: WHAT I WANTED
THE STUDENTS
TO NOTICE OR RECOGNIZE
IS THAT THERE ARE
OTHER DECOMPOSERS
THAT ARE NOT
SO OBVIOUS,
THAT THERE ARE THINGS
GOING ON THAT AID
THE DECOMPOSITION PROCESS
ALL THE TIME
THAT MAY NOT BE SO READILY
RECOGNIZABLE TO US.
WE'VE GOT DECOMPOSERS
AT WORK.
THE STUDENTS ARE VERY
USED TO EVENTS
THAT HAVE CAUSES
AND EFFECTS
THAT THEY CAN SEE
DIRECTLY.
BUT THEY HAVE
A HARD TIME
WITH MICROSCOPIC
LIFE FORMS
THAT ONLY LEAVE
TRACE EVIDENCE
OF BEING THERE
THROUGH THEIR ACTIVITY.
EVEN WHEN PRESENTED
WITH THE EVIDENCE
OF DECOMPOSITION,
CHILDREN OFTEN HAVE
DIFFICULTY
UNDERSTANDING
THE PROCESS.
WE ASKED PJ AND MICHAEL
TO SHARE THEIR IDEAS
ABOUT DECOMPOSITION.
SO IF I TOOK THAT BREAD OUT
AND I STUCK IT RIGHT HERE
ON THE TABLE.
HOW WOULD IT DECOMPOSE?
UM, I DON'T THINK IT
COULD BE DECOMPOSED
BECAUSE IT'S NOT NEAR OR AROUND WHERE
FUNGUS COULD GROW.
IT DOESN'T JUST DECOMPOSE
ON ITS OWN.
IT HAS TO HAVE FUNGUS.
IF YOU LEAVE A SANDWICH OUT
ON A TABLE FOR TWO WEEKS,
IT WOULD ROT.
BUT THERE'S NO SOIL
AROUND IT.
SO IT WOULD DEcompose.
FUNGUS GROWS ON IT.
FUNGUS GROWS
ON DEAD STUFF.
EXACTLY IF WE LEFT
WOULD WHAT DO
CAUSING BUT SOMETHING
SEALED THE BREAD
THAT ARE OTHER
THAT THERE THEY'RE
A SITUATION SO IT CREATES
SEE THEM.

BECAUSE IT PROVIDES THE NUTRIENTS AND...
I HAVE NO IDEA HOW FUNGUS GROWS.
FUNGUS IS A LOT DIFFERENT THAN MANY THINGS ON THIS PLANET.

EXACTLY IF WE LEFT
WOULD WHAT DO
CAUSING BUT SOMETHING
SEALED THE BREAD
THAT ARE OTHER
THAT THERE THEY'RE
A SITUATION SO IT CREATES
SEE THEM.

PROBLEMATIC THE MICROBES FREQUENTLY A PLACE WHERE LOTS OF THINGS GETS TO CHOOSE I WOULD
BUILDING.

THE FUNGUS GROWS, I WOULD LIKE YOU TO PREDICT WHAT YOU THINK MIGHT HAPPEN.

THE BREAD IS SLOWLY BACTERIA IS GROWN AND CONSUMED ON WASTES AND HAVE HEARD OF FUNGI, BUT THEY ARE VERY UNCLEAR ABOUT WHERE THESE ORGANISMS COME FROM AND HOW THEY GROW.

DECOMPOSER ORGANISMS THRIVE ON WASTES AND DEAD PLANTS AND ANIMALS. WE TAPED THE DECOMPOSITION OF THIS RAT OVER A SIX-WEEK PERIOD. THE RAT'S MATERIAL BODY IS SLOWLY BEING CONSUMED BY BACTERIA AND FUNGI THAT LANDED ON IT AND HAVE GROWN THERE. THEN WE TOOK A SAMPLE FROM THE RAT AND PUT IT UNDER A MICROSCOPE TO GET A GLIMPSE OF THE BACTERIA AT WORK.

HERE THEY ARE. Zook: MARY ANN BERNSTEIN'S CLASS CONTINUES ITS STUDY OF DECOMPOSERS, NOW THEY'RE EXPERIMENTING WITH BREAD MOLD, A TYPE OF FUNGUS.

YOU'RE GOING TO TAKE THE PIECE OF BREAD, NICE, FRESH, SOFT BREAD.

YOU'RE GOING TO GENTLY RUB ONE SIDE OF THE BREAD SOMEPLACE IN THIS BUILDING.

I WOULD LIKE YOU TO CHOOSE A PLACE THAT GETS LOTS OF TRAFFIC.

A PLACE WHERE PEOPLE FREQUENTLY GO.

THE MICROBES ARE PROBLEMATIC FOR KIDS BECAUSE YOU CAN'T SEE THEM.

SO IT CREATES A SITUATION WHERE THEY'RE FORCED TO RECOGNIZE THAT THERE ARE OTHER THINGS AT WORK THAT ARE NOT VISIBLE.

THE BREAD HAS BEEN SEALED IN THE BAG, BUT SOMETHING IS AT WORK CAUSING THE DECOMPOSITION.

WHAT DO YOU THINK WOULD HAPPEN IF WE LEFT THEM UP HERE EXACTLY THE WAY THEY ARE UNTIL YOU CAME BACK TO SCHOOL IN SEPTEMBER?

OH, MY GOSH!

OH, MY GOSH!

NICKY, LOOK AT MINE!

LOOK AT IT!
OH, MY GOSH, CONNOR!
[CHILDREN TALKING EXCITEDLY]
Bernstein: WE'LL TAKE A COUPLE OF THESE SAMPLES INSIDE, WE'LL PUT THEM ON THE MICROSCOPE, AND YOU'LL BE ABLE TO TAKE A CLOSER LOOK AT THEM ON THE SCREEN.
Children: OOH! Boy: THAT IS LIKE FUZZ!
Girl: IT LOOKS LIKE JELLY!
Girl #2: NO, IT DOESN'T.
[CHILDREN DISCUSSING IMAGES]
Narrator: MICROBES ARE EVERYWHERE. MICROSCOPIC MOLD SPORES ARE ABUNDANT IN SCHOOL S AND HOMES. THEY'RE FLOATING IN THE AIR AND LIVE ON MOST SURFACES. ON CONTACT WITH A FOOD SUPPLY, THEY GROW TO THE POINT WHERE THEY'RE OFTEN VISIBLE TO THE NAKED EYE. WITH DECOMPOSERS AROUND, NOTHING GOES TO WASTE. THEY USE FOOD TO GROW AND REPRODUCE. LIKE ALL ORGANISMS, DECOMPOSERS OCCUPY THE Niche AT THE END OF THE FOOD CHAIN. BUT WHAT DOES THAT MEAN FOR MATTER? WHAT HAPPENS TO ALL THE MATTER AFTER DEATH AND DECAY?
WE ASKED THE CHILDREN IN OUR SCIENCE STUDIO, CAN THE MATTER IN DEAD THINGS EVER BE LIVING MATTER AGAIN?
NONLIVING CANNOT BECOME ALIVE. BUT, UH...
NONLIVING CANNOT BECOME DEAD, BECAUSE DEAD... YOU HAVE TO BE ONCE LIVING TO BECOME DEAD. AND LIVING CAN BECOME DEAD, AND DEAD CAN BECOME NONLIVING. LIVING BECOMES DEAD AND DEAD BECOMES NONLIVING, EVENTUALLY. BUT THERE'S NO WAY THE NONLIVING CAN BECOME LIVING AGAIN? NO.
SO IT'S A ONE-WAY STREET? IT'S LIVING, DEAD, NONLIVING -- IT'S ONE-WAY.
THE CHILDREN DESCRIBE INTERACTIONS BETWEEN LIVING, NONLIVING, AND DEAD THINGS WITH CONFIDENCE.
THEY THINK THAT THE PATH LIVING THINGS TAKE IS LINEAR -- LIVING, DEAD, NONLIVING -- AND THAT THAT'S THE END OF THE LINE. WE NOW KNOW MATTER IS NEITHER CREATED NORDestroyed. SO IF PJ AND MICHAEL ARE RIGHT, WE SHOULD EXPECT TO SEE AN ACCUMULATION OF NONLIVING MATTER PILING UP ALL OVER THE WORLD. LET'S SEE WHAT GREG AND MAGGY THINK ABOUT THE ONE-WAY STREET. SO THE DIRTS IN THE GROUND, AND HOW IS IT USED?
CAN YOU KIND OF EXPLAIN USING ANY OF THESE ANIMALS AND PLANTS IN HERE? WORMS EAT DIRT, I THINK.
Greg: YEAH, WORMS EAT DIRT. THEN THEY GO TO THE BATHROOM. AND THEN THERE'S MORE DIRT. WELL, IT'S THE SAME AMOUNT OF DIRT, BUT -- AND THEN THERE'S DIRT AGAIN, AND THEN IT JUST KEEPS GETTING REUSED BY THE WORMS, OR ANYTHING ELSE THAT USES DIRT. CAN YOU THINK OF ANYTHING ELSE IN THE PICTURE THAT EATS DIRT? MUSHROOMS, 'CAUSE THEY'RE CONNECTED TO THE GROUND, WHICH MEANS -- AND TO THE TREES. THAT'S WHERE THEY GET THEIR NUTRIENTS, TO MAKE...
TO KEEP THEM ALIVE. IN THIS CONVERSATION, GREG AND MAGGY HINT AT CYCLING WHEN THEY SAY THAT THE SOIL KEEPS GETTING REUSED OVER AGAIN AS A SOURCE OF NUTRIENTS, ALTHOUGH THEY SEEM TO THINK THAT SOILS ONLY WERE USED BY WORMS, WHICH EXPLANATION FITS THE FACTS?
IS THE PATH TAKEN BY MATERIALS A ONE-WAY STREET, AS PJ AND MICHAEL BELIEVE?
OR IS IT A CYCLE, AS GREG AND MAGGY SUGGEST?
Narrator: CONSIDER THE SIGNATURE ELEMENT OF THE LIVING WORLD -- CARBON. WHAT PATH DOES IT TAKE?
ON THE JUSTIFICATION OF DECOMPOSITION, IS THROUGH AND LEAVES CARBON EXITS THE MAJOR OF THOUSANDS FOR A PERIOD IT'S LIKELY INTO THE ATMOSPHERE IF THAT processes DEPENDING OR SEVERAL IT MAY ALIVE FOR THAT TREE POOL OF CARBON IT WOULD INTO THE ATMOSPHERE TO ENTER, THIS IMPLIES THAT CARBON CYCLES BACK AND FORTH BETWEEN PLANTS AND THE AIR. BUT IN ACTUAL FACT, IT DOES MUCH MORE. EVERY LIVING THING PLAYS A ROLE IN CARBON CYCLING. NEARLY EVERY ORGANISM RESPIRES FROM THE BACTERIA AT WORK IN COMPOST PILES TO GREEN, LEAFY PLANTS. LET'S TAKE A LOOK AT THE REST OF THE CARBON CYCLE WITH DR. FINZL. THE AMOUNT OF TIME THAT CARBON RESIDES IN AN ECOSYSTEM DEPENDS UPON WHERE THAT CARBON ATOM IS FOUND. IF CARBON ENTERS INTO A LEAF IT WILL ONLY STAY IN THE ECOSYSTEM FOR A PERIOD OF MONTHS TO YEARS AS A RESULT OF THE PROCESS OF DECOMPOSITION. YOU CAN SEE ALL THESE LEAVES ON THE GROUND HERE, AND AS SOON AS THEY HIT THE GROUND, BACTERIA AND FUNGI BEGIN TO DECOMPOSE THOSE LEAVES, AND A PRODUCT, A BY-PRODUCT OF THE PROCESS OF DECOMPOSITION, IS THE RETURN OF CARBON TO THE ATMOSPHERE IN THE FORM OF CO2. IF THAT CARBON ATOM WERE TO ENTER, SAY, INTO THE TRUNK OF A TREE, IT WOULD RESIDE IN THAT POOL OF CARBON FOR AS LONG AS THAT TREE IS ALIVE, AND THAT TREE MAY BE ALIVE FOR 20 YEARS, IT MAY BE ALIVE FOR 50 YEARS, OR SEVERAL HUNDRED YEARS. DEPENDING UPON THE ECOLOGICAL PROCESSES THAT TAKE PLACE HERE. IF THAT CARBON ATOM ENTERS INTO THE SOIL, IT'S LIKELY TO STAY IN THE SOIL FOR A PERIOD OF THOUSANDS OF YEARS. THE MAJOR MECHANISM BY WHICH CARBON EXITS SOILS AND LEAVES THE ECOSYSTEM IS THROUGH THE PROCESS OF DECOMPOSITION. JUST LIKE THESE FRESH LEAVES ON THE GROUND HERE BEING CONSUMED BY SOIL MICROORGANISMS, AND RETURN TO THE ATMOSPHERE AS CO2, OR LOST FROM THE SOIL ECOSYSTEM AS A RESULT OF WATER MOVING THROUGH THE SOIL, AND DELIVERING THAT CARBON ATOM INTO STREAMS AND LAKES. THERE ARE LARGE VARIATIONS IN THE AMOUNT OF CARBON THAT ENTER AND EXIT AN ECOSYSTEM WITHIN THE COURSE OF A DAY. PHOTOSYNTHESIS ONLY OCCURS DURING DAYLIGHT HOURS, WHEREAS RESPIRATION OCCURS ALL DAY LONG. WE CAN ESTIMATE THE AMOUNT OF CARBON THAT'S BEING ACUMULATED OR BEING LOST FROM AN ECOSYSTEM ON A DAILY BASIS, OR ON AN ANNUAL BASIS, BY MEASURING THE total amount OF CARBON THAT ENTERS INTO THE ECOSYSTEM THROUGH THE PROCESS OF PHOTOSYNTHESIS AND THE TOTAL AMOUNT OF CARBON THAT LEAVES THE ECOSYSTEM THROUGH THE PROCESS OF RESPIRATION, DURING OUR MEASUREMENT PERIODS, IF THE RATE OF PHOTOSYNTHESIS IS GREATER THAN THE RATE OF RESPIRATION, THE ECOSYSTEM IS ACCUMULATING CARBON. ON THE OTHER HAND, IF, DURING OUR MEASUREMENT PERIODS, RESPIRATION RATES ARE GREATER THAN THE RATE OF PHOTOSYNTHESIS, THEN THE ECOSYSTEM HAS LOST CARBON. THE METHOD SCIENTISTS USE TO TEST FOR THE PRESENCE OF CYCLING ELEMENTS ARE CONDUCTED WITH Sophisticated equipment THAT YIELDS VERY PRECISE MEASUREMENTS. THIS SOIL SAMPLE KIT IS LESS PRECISE, BUT IT DOES HELP TO ILLUSTRATE HOW WE KNOW THAT A CERTAIN ELEMENT IS PRESENT OR NOT. WE PUT A SAMPLE OF SOIL IN TWO CONTAINERS TO SEE WHICH ELEMENTS WE COULD DETECT. WE FOUND NITROGEN AND PHOSPHOROUS IN OUR SAMPLE. NOW LET'S RETURN TO DR. SHEATS TO EXPLORE THE PATH NITROGEN TAKES THROUGH ECOSYSTEMS. Sheats: let's talk about how nitrogen can be cycled. THERE'S A LOT OF NITROGEN IN THE AIR. THE PROBLEM WITH RESPECT
TO LIVING ORGANISMS
IS THAT THE NITROGEN
IN THE AIR,
IT’S NOT IN A FORM
THAT WE CAN USE.
BUT TO THE RESCUE COME
OUR NITROGEN-FIXING
BACTERIA.
THEY FIX NITROGEN.
THEY CAN PASS
THE NITROGEN TO A PLANT,
AND THE PLANT WILL THEN
TAKE NITROGEN
AND INCORPORATE IT INTO
ITS BODY TISSUES.
EVENTUALLY, LIKE ALL OTHER
LIVING ORGANISMS,
THE PLANT DIES.
ONCE THE PLANT DIES,
WE GO BACK TO BACTERIA.
BACTERIA TAKE THE PLANT TISSUES AND
BREAK THEM DOWN.
SOME OTHER BACTERIA
CAN COME ALONG
AND USE THIS NITROGEN THAT’S
NOW IN A DIFFERENT FORM
AND CONVERT IT BACK.
TO A GAS.
SO NOW THE NITROGEN IS
BACK INTO THE ATMOSPHERE.
AND THEN THE CYCLE
CAN BE REPEATED AGAIN.
AND AGAIN.
AND AGAIN.
WE ASKED.
WHERE DOES THE MATTER GO?
AND WE CAN NOW SEE
THAT CARBON AND NITROGEN,
OUR REPRESENTATIVE EXAMPLES,
CYCLE FROM THE NONLIVING
TO THE LIVING WORLD, AND BACK.
THE PATHS AND RATES
MAY VARY.
BUT ALL MATERIALS CYCLE
THROUGH ECOSYSTEMS
OVER AND OVER AGAIN.
PLEASE VISIT OUR WEBSITE
TO LEARN
ABOUT OTHER MATERIAL
CYCLES.
IT’S TIME TO CATCH UP
WITH BOTTLE BIOLOGY TO SEE
HOW PAUL WILLIAMS’ INVENTIVE ECOSYSTEMS
ARE PROGRESSING.
HELLO, IT’S BEEN QUITE
A JOURNEY WITH BOTTLE BIOLOGY.
IT’S HARD TO BELIEVE THAT THIS IS OUR LAST
SESSION TOGETHER.
THE GOOD NEWS IS THAT YOU CAN KEEP YOUR
BOTTLE SYSTEM GOING
AND MAYBE EVEN TRY
ANOTHER ONE.
EACH SYSTEM IS DESIGNED
TO BRING
OUR ESSENTIAL SCIENCE TOPICS
TO LIFE.
YOU CAN USE THE TERRAQUA
COLUMN
TO HELP YOUR STUDENTS ANSWER
THE QUESTION, "WHAT IS LIFE?"
IT ALSO PROVIDES LIVING EXAMPLES FOR
CLASSIFICATION
OF PLANTS, ANIMALS, FUNGI,
PROTEASE, AND EVEN TINY
LIFE FORMS LIKE BACTERIA.
THE BRASSICA AND BUTTERFLY

SYSTEM
COMBINES TWO LIFE CYCLES
THAT ARE INTERTWINED,
AN ANIMAL AND A PLANT
WORKING TOGETHER TO REPRODUCE.
THE FUNDAMENTS
OF EVOLUTION --
VARIATION, ADAPTATION,
AND NATURAL SELECTION --
CAN BE INTRODUCED IN
AN ELEGANT EXPERIMENT
USING THE FIELD POPULATION.
THE ECOCOLUMN PROVIDES
MANY EXAMPLES
OF HOW ENERGY FLOWS
AND MATERIALS CYCLE.
THROUGH AN ECOSYSTEM.
THROUGH BOTTLE BIOLOGY,
I HOPE YOU AND YOUR STUDENTS
WILL BE CONVINCED
OF THE INTERDEPENDENCE
BETWEEN LIVING THINGS
AND THEIR ENVIRONMENT.
REMEMBER, MATERIALS ARE
EASY TO FIND
AND THE POSSIBILITIES
ARE LIMITLESS.
THIS IS PAUL WILLIAMS
SIGNING OFF FOR BOTTLE BIOLOGY.
THANKS, PAUL.
ECOSYSTEMS NATURALLY GROW
AND CHANGE WITH TIME.
BOTTLE BIOLOGY IS ONE WAY
TO SEE THIS IN ACTION.
ECOSYSTEMS ARE IN DYNAMIC BALANCE
WHEN THE FLOW
OF MATERIALS IS STEADY.
BECAUSE THE PARTS OF ECOSYSTEMS
ARE SO INTERCONNECTED,
CHANGES TO THE WAY
MATERIALS CYCLE
CAN HAVE CASCADE CONSEQUENCES
TO THE ENVIRONMENT.
IN THE LAST PART
OF TODAY’S SESSION,
WE’LL BRIEFLY CONSIDER
THE EFFECTS OF CYCLES
THAT ARE OUT OF BALANCE.
WHEN APPLIED
IN LARGE QUANTITIES,
MANMADE FERTILIZERS PROVIDE
MORE AVAILABLE NITROGEN
THAN THE CROPS CAN USE.
WHAT HAPPENS
TO THE EXCESS NITROGEN?
DR. NICKY SHEATS EXPLAINS
HOW NITROGEN FERTILIZER
CAN IMPACT
AN AQUATIC ECOSYSTEM.
Sheats: WE HAVE A PROBLEM
IN THIS COUNTRY
AND OTHER PLACES
IN THE WORLD
WHERE RIVERS, ESTUARIES
NEAR HUMAN POPULATIONS,
SOMETIMES THEY HAVE TOO MUCH
NITROGEN IN THEM.
AND PART OF THIS IS DUE
TO FERTILIZER.
THAT’S RUN OFF FROM
ADJACENT FIELDS.
SO, THE PROBLEM WITH
TOO MUCH NITROGEN
IS THAT IT CAN CAUSE
MORE LIFE IN ESTUARY.
IN PARTICULAR, MORE LIFE.
IN THE FORM OF THE PLANTS
THAT ARE IN THE WATER,
BACTERIA IN THE WATER,
AND THAT LIFE,
LIKE OTHER LIFE, USES OXYGEN.
THEY'LL USE UP
THE OXYGEN IN THE WATER,
AND THAT'S NOT GOOD
FOR THE ANIMALS IN THE WATER,
SO THEN IF YOU
FISH IN THE WATER,
THEY MAY NOT HAVE
ENOUGH OXYGEN,
SO, PRETTY SOON ALL YOU HAVE
IN THE RIVER
ARE PLANTS AND BACTERIA.
Narrator: DISRUPTIONS
IN THE CARBON CYCLE
CAN BE EQUALLY HARMFUL
TO ECOSYSTEMS.
DINIZI STUDIES THE EFFECTS
OF EXCESS CARBON
IN FOREST ECOSYSTEMS.
THERE ARE THREE PROCESSES
BY WHICH HUMAN ACTIVITY
MODIFIES THE AMOUNT OF CARBON IN
TERRESTRIAL ECOSYSTEMS.
THAT INCLUDES THE HARVEST
OF FOREST TREES,
AGRICULTURE,
AND THE COMBUSTION
OF FOSSIL FUELS.
THE COMBUSTION OF FOSSIL FUELS
REPRESENTS
A TRANSFER OF CARBON
THAT HAS BEEN STORED
FOR TENS TO HUNDREDS
OF MILLIONS OF YEARS
IN GEOLOGICAL DEPOSITS
AND DELIVERS IT
TO THE EARTH'S ATMOSPHERE.
THE RECENT RISE
IN THE CONCENTRATION
OF CARBON DIOXIDE
IN THE EARTH'S ATMOSPHERE
IS NOW KNOWN TO HAVE CAUSED
AN INCREASE
IN THE EARTH'S SURFACE
TEMPERATURE,
NATURAL ECOSYSTEMS,
LIKE FORESTLANDS
AND GRASSLANDS,
HAVE AN ABILITY TO ASSIMILATE
CARBON DIOXIDE
FROM THE ATMOSPHERE
THROUGH THE PROCESS
OF PHOTOSYNTHESIS.
AND RECENT STUDIES SHOW
THAT THE RISE IN ATMOSPHERIC CARBON
DIOXIDE CONCENTRATIONS
THAT'S ASSOCIATED WITH
THE COMBUSTION OF FOSSIL FUELS
HAS INCREASED THE AMOUNT
OF CARBON BEING STORED
IN TERRESTRIAL ECOSYSTEMS.
SOME HAVE ARGUED THAT
THE STIMULATION IN PLANT GROWTH
AS A RESULT OF HIGH
CARBON DIOXIDE CONCENTRATIONS
WILL SOLVE GLOBAL WARMING.
THAT IS, NATURAL ECOSYSTEMS
WILL ABSORB EXCESS CO2
THAT'S DELIVERED INTO
THE EARTH'S ATMOSPHERE
AS A RESULT
OF FOSSIL FUEL COMBUSTION.

HOWEVER, THE PROJECTED
AMOUNT OF CARBON
IN THE EARTH'S ATMOSPHERE
ASSOCIATED WITH
FOSSIL FUEL COMBUSTION
OVER THE NEXT 100 YEARS
FAR EXCEEDS THE CAPACITY
OF NATURAL ECOSYSTEMS
TO ABSORB CARBON DIOXIDE.
LIFE IN TERRESTRIAL
AND AQUATIC ECOSYSTEMS
ARE LINKED BY MATTER.
A CLOSE LOOK
AT MATERIAL CYCLES
REMEMDS US
HOW INTERDEPENDENT
THE LIVING AND
NONLIVING WORLDS ARE.

Grisham: THERE IS A FINITE AMOUNT OF MATTER
ON EARTH.
THIS MATTER FORMS
THE BUILDING BLOCKS OF LIFE
AND IS FOUND IN SOIL, ROCKS,
AND AIR.
THE MATTER IMPORTANT TO ALL LIFE
IS REPRESENTED IN
THE SPONCH CaFe MNEMONIC.
Zook: THE MATTER CYCLES
THROUGH FOOD CHAINS
AND RETURNS
TO THE NONLIVING WORLD
AND THEN CYCLES BACK INTO
NEW FOOD CHAINS,
THE HEALTH OF ECOSYSTEMS,
WHICH INCLUDES ALL OF US,
ULTIMATELY DEPENDS
ON THE CYCLING OF MATTER.
WELL, WE'VE COME
A LONG WAY TOGETHER.
LET'S LOOK BACK AT
SOME OF THE BIG IDEAS
THAT WE'VE EXPLORED
THROUGHOUT THE COURSE.
Narrator: IN SESSION ONE,
WE ASKED "WHAT IS LIFE?"
AND DISCOVERED THAT
FIVE CHARACTERISTICS
UNITE ALL LIVING
ORGANISMS,
LIFE IS BUILT FROM CELLS,
SINGLE OR MULTICELLED,
ALL ORGANISMS HAVE LIFE SPANS,
WHICH START
WITH A LIVE BEGINNING
AND END IN DEATH --
WITH GROWTH,
DEVELOPMENT,
AND REPRODUCTION
IN BETWEEN.
LIFE REQUIRES A CONSTANT SUPPLY OF
MATTER AND ENERGY
TO RESPOND TO CHANGING
ENVIRONMENTS,
BOTH INSIDE AND OUTSIDE
THE ORGANISM.
ALL OF THESE BIOLOGICAL RESPONSES
ARE ULTIMATELY CONTROLLED
BY THE HEREDITARY MATERIAL
DNA.

DESPITE THE UNIFYING
CHARACTERISTICS OF LIFE,
WE INHABIT A WORLD OF DIVERSITY,
WHERE WIDELY DIFFERENT LANDSCAPES
ARE INHIBITED BY
AN ARRAY OF PLANTS, ANIMALS,
AND OTHER ORGANISMS.
IN OUR SECOND SESSION, WE EXPLORED WAYS TO MAKE SENSE OF DIVERSITY BY LOOKING AT CLASSIFICATION SYSTEMS BASED ON CELL FEATURES. CURRENTLY THREE DOMAINS ARE USED TO CLASSIFY ALL LIFE FORMS, WITH THOSE MOST FAMILIAR TO US GROUPED INTO FOUR KINGDOMS. SESSIONS THREE AND FOUR LOOKED MORE CLOSELY AT THE LIFE CYCLES OF ANIMALS AND PLANTS. WE LEARNED HOW SEXUAL REPRODUCTION INVOLVES DNA CONTRIBUTED BY TWO PARENTS, EACH PASSING EXACTLY HALF OF THEIR CHROMOSOMES TO A FERTILIZED EGG. OUR STUDY OF PLANTS SHOWS THAT THEY REPRODUCE SEXUALLY, TOO, WITH FLOWERS, FRUITS, AND SEEDS.

LIFE CYCLES OF INDIVIDUAL ORGANISMS BROUGHT US TO THE LEVEL OF POPULATIONS. IN SESSION FIVE, WE CONSIDERED THE FUNDAMENTALS OF EVOLUTION -- WE OBSERVED THAT ALL POPULATIONS -- PLANTS AND ANIMALS -- VARY TREMENDOUSLY IN THEIR TRAITS AS A RESULT OF VARIATION IN GENES. ADAPTATION THROUGH NATURAL SELECTION IS THE RESULT OF VARIATION THAT PROVIDES SURVIVAL AND REPRODUCTIVE ADVANTAGE TO CERTAIN INDIVIDUALS IN A POPULATION. IN SESSION SIX, WE STUDIED HOW NEW SPECIES COME INTO BEING, AS POPULATIONS ADAPT TO NEW AND CHANGING ENVIRONMENTS. THE TREE OF LIFE IS A MODEL USED TO DESCRIBE HOW MILLIONS OF SPECIES EVOLVED ON EARTH AND HOW THEY ARE RELATED TO EACH OTHER THROUGH COMMON ANCESTORS.

WE MOVED TO THE LEVEL OF COMMUNITIES IN SESSION SEVEN, WHERE PHOTOSYNTHESIS AND CELL RESPIRATION EMERGED AS THE TWO PROCESSES THAT HARNESS ENERGY THAT SUPPORTS ALMOST ALL LIFE ON EARTH. IN THIS, OUR FINAL SESSION, WE LOOKED AT THE MATTER THAT MAKES UP LIFE, AND HOW INTERLINKED LIFE AND MATTER ARE TO ECOSYSTEMS. MATTER CYCLES FROM THE NONLIVING TO THE LIVING WORLD, AND BACK, AGAIN AND AGAIN.

WE REALLY HAVE COME A LONG WAY, AND WE HOPE THAT THE CONTENT YOU’VE EXPLORED WITH US WILL HELP YOU BECOME MORE COMFORTABLE AND CONFIDENT IN BRINGING THE EXCITEMENT OF LIFE SCIENCE TO YOUR STUDENTS. THANK YOU FOR PARTICIPATING IN THIS COURSE. Both: GOODBYE.

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