FUNDING FOR THIS PROGRAM
IS PROVIDED BY ANNENBERG/CPB

TO ADVANCE EXCELLENT TEACHING.

HIDDEN BELOW THE SERENE CAMPUS OF HARVARD UNIVERSITY

LIES A SECRET CHAMBER

DEVOTED TO THE DEAD.

A VAULT PACKED TO THE RAFTERS

WITH THE REMAINS OF REPTILES
AND AMPHIBIANS,

PRESERVED IN CENTURY-OLD SPECIMEN JARS

LIKE THE DECANTED
NIGHTMARES OF CHILDHOOD.

LETHAL VIPERS,

POISONOUS FROGS,

AND A WITCH'S BREW OF NEWTS, SALAMANDERS, AND LIZARDS.

ALL TOGETHER,
MILLIONS OF SPECIMENS

THAT MAKE UP THE COLLECTION OF REPTILES AND AMPHIBIANS

AT THE MUSEUM OF
COMPARATIVE ZOOLOGY.

WHY ARE THEY HERE?

AND IN SUCH NUMBER?

IN THEIR BODIES
AND IN THEIR DNA,

ARE CLUES THAT HELP
SCIENTISTS REVEAL

HOW EVOLUTION HAS SHAPED
AND RESHAPED THE LIVING PLANET.

IN THE SUBTLE SPECTRUM
OF THEIR VARIED FORMS,

THEY LEAD US TO ASK,
HOW CAN WE MAKE SENSE

OF LIFE'S VAST DIVERSITY?

HOW CAN NEW LIFE FORMS ARISE?

AND WHERE CAN WE LOOK FOR
THE SHARED ORIGINS

THAT BIND ALL LIVING THINGS
TO EACH OTHER

AND TO A COMMON HISTORY

THAT MAY REACH 4 BILLIONS YEARS INTO THE PAST

TO THE VERY DAWN OF LIFE ITSELF?

HELLO, AND WELCOME BACK
TO "ESSENTIAL SCIENCE."

THIS IS SESSION SIX

IN THE LIFE SCIENCES SERIES,

A CONTENT COURSE FOR ELEMENTARY SCHOOL TEACHERS.

IF YOU'RE EVER LUCKY ENOUGH TO PAY A VISIT TO THE MUSEUM

OF COMPARATIVE ZOOLOGY
AT HARVARD UNIVERSITY,

YOU'RE SURE
TO BE IMPRESSED.

NOT ONLY BY THE STUNNING VARIETY OF ANIMALS ON DISPLAY

BUT ALSO BY
THE SINGLE-MINDED DEDICATION

OF THE COLLECTORS
WHO TRAVELLED THE EARTH

IN AN ATTEMPT TO CATALOGUE
THE LIVING WORLD.

FROM THEIR EFFORTS WE HAVE
AN AMAZING RESOURCE,

FROM WHICH WE CAN BUILD
A STORY OF LIFE ON EARTH,

THAT IS,
A STORY OF EVOLUTION.

IN THE LAST SESSION

WE BEGAN OUR EXAMINATION
OF EVOLUTION.

WE OBSERVED THAT WITHIN POPULATIONS OF ORGANISMS,

VARIATION APPEARS
IN EVERY GENERATION.

IF A SPECIFIC VARIATION
HELPS CERTAIN INDIVIDUALS

SURVIVE BETTER THAN OTHERS
IN THEIR ENVIRONMENT,

THEN OVER MANY GENERATIONS,

THEIR DESCENDANTS WILL
BECOME MORE NUMEROUS.

AS THIS HAPPENS,
THAT BENEFICIAL VARIATION

WILL BECOME MORE COMMON IN
THE POPULATION AS A WHOLE.

IN THIS WAY, POPULATIONS
AND NOT INDIVIDUALS,

ARE SAID TO ADAPT
TO THEIR ENVIRONMENT

THROUGH A PROCESS CALLED
NATURAL SELECTION.

THIS IS EVOLUTION AT WORK.

IN TODAY'S SESSION,
WE WILL CONTINUE TO CONSIDER

HOW VARIATION AND ADAPTATION THROUGH NATURAL SELECTION

DRIVE THE EVOLUTION OF SPECIES,

THE MILLIONS
OF DIFFERENT LIFE FORMS

THAT POPULATE OUR PLANET

AND MAKE UP A THRIVING
TREE OF LIFE.

WE'LL ASK,
WHAT IS A SPECIES?

AND LEARN THAT
FINDING AN ANSWER

CAN BE TRICKIER
THAN IT SEEMS.

WE'LL EXPLORE
HOW SCIENTISTS BELIEVE

THAT NEW SPECIES EVOLVE
FROM EXISTING SPECIES.

AND WE'LL LOOK AT
COMPELLING EVIDENCE

FOR THE RELATEDNESS
OF SPECIES

NOT JUST TO EACH OTHER,

BUT TO ANCIENT CREATURES
LONG VANISHED.

THE VERTEBRATES WITHIN
THE ANIMAL KINGDOM

WILL BE THE SOURCE
OF OUR EXAMPLES,

INCLUDING OUR REPTILIAN
FRIENDS AT THE MUSEUM.

HOWEVER, THE IDEAS WE'LL
EXPLORE ABOUT EVOLUTION

APPLY TO THE VAST DIVERSITY
OF LIFE ON EARTH.

DR. KAREN WORTH
HAS SEEN HOW EAGERLY

CHILDREN DIVE
INTO ACTIVITIES

THAT LINK BEAUTIFULLY
TO THE STUDY OF EVOLUTION,

ACTIVITIES THAT EXPLORE THE SIMILARITIES AMONG ORGANISMS

THAT AT FIRST SEEM
TO HAVE LITTLE IN COMMON.

AT THIS AGE LEVEL,
THE FIRST INSTINCT IS TO SAY

EVERYTHING IS TOTALLY DIFFERENT.

THE CAT IS DIFFERENT FROM A DOG IS DIFFERENT FROM A HORSE

IS CERTAINLY DIFFERENT FROM ME.

BUT AS THEY LOOK MORE CLOSELY AT THE SKELETONS --

IF YOU TAKE AWAY

ALL OF THAT OUTER COVERING,

IT'S VERY HARD NOT TO SEE
THE RIBS, FOR EXAMPLE,

THAT CROSS DIFFERENT SKELETONS.

IT'S VERY HARD NOT TO SEE

THE STRUCTURE OF THE LIMBS

THAT APPEAR IN
A VARIETY OF FORMS.

SO CHILDREN BEGIN --

IF ASKED TO MAKE
THESE COMPARISONS,

THEY CAN BEGIN TO SORT OUT
WHAT IS DIFFERENT

BUT THEN ALSO WHAT IS SIMILAR.

LIKE, A LONG,
LONG TIME AGO,

THEY COULD HAVE BEEN
IN A WAY RELATED.

LIKE, THERE COULD
HAVE BEEN SOMETHING

THAT CONNECTED
THEM ALL TOGETHER.

IF YOU DON'T SEE
THE SIMILARITIES

AS WELL AS THE DIFFERENCE,

IT'S VERY HARD TO START
TRACKING BACK

AND SAY, OKAY, IF THEY
ARE SIMILAR BUT DIFFERENT,

HOW DID THEY GET THAT WAY?

WHY DO WE ALL HAVE SOMETHING THAT RESEMBLES ARMS,

OR SOMETHING THAT COULD BE CONCEIVED OF AS ARMS?

BUT THEY'RE SO DIFFERENT ALSO AND USED IN SUCH DIFFERENT WAYS.

AND YET THEY ARE STILL FROM
A CHILD'S PERSPECTIVE "ARMS."

SO I THINK THAT THERE ARE COMMONALITIES ACROSS

VERY, VERY DIFFERENT,

SEEMINGLY VERY DIFFERENT, ORGANISMS, OR CREATURES.

AND I BELIEVE THAT
THAT IDEA

IS REALLY A VERY
POWERFUL PRECURSOR

TO THEM LOOKING AT HOW

THESE DIFFERENCES
HAVE EVOLVED OVER TIME.

DR. WORTH SUGGESTS TO US THAT SIMILARITIES AMONG SPECIES,

SUCH AS CERTAIN
BONES IN ANIMALS,

MAY BE CLUES TO LIFE'S PAST,

A PAST THAT WE BELIEVE LINKS ALL SPECIES TO ONE ANOTHER,

FROM THE MOST ANCIENT
TO THE MOST RECENT.

FOR EXAMPLE,
BOTH A FROG HERE

AND A DOG
HAVE FORELIMBS.

BUT THE FORM VARIES
BETWEEN THE TWO.

AND DATA FROM
FOSSIL EVIDENCE

INDICATES THAT
THE FIRST LIFE FORMS

WERE VARIOUS MICROBES,

MICROBES THAT WERE PERHAPS
LIKE THESE BACTERIA

THAT INHABIT BOILING SULFUR
HOT SPRINGS TODAY.

THERE IS COMPELLING EVIDENCE

THAT LIFE HAS CONTINUED TO EVOLVE AND DIVERSIFY

FROM THESE ANCIENT CREATURES
AS NEW LIFE FORMS BRANCH OUT

FROM COMMON ANCESTORS.

Grisham: IMAGINE IF WE COULD SOMEHOW OBSERVE

THE GROWTH OF A TREE OF LIFE FROM THIS ANCIENT BASE

TO THE TIPS OF ITS MILLIONS
OF MODERN BRANCHES.

WHAT MIGHT WE SEE?

SINGLE-CELLED CREATURES

DEPEND UPON FOOD
IN THE ANCIENT SEAS

EVOLVING TO USE THE SUN'S ENERGY TO MAKE THEIR OWN FOOD.

ANIMAL-LIKE MICROBES COMPOSED
OF ONLY ONE CELL

EVOLVING TO SIMPLE AND THEN EVEN MORE COMPLEX MANY-CELL FORMS.

AQUATIC PLANTS AND ANIMALS

ADAPTING TO SURVIVE
AWAY FROM WATER.

PREHISTORIC REPTILES MAKING
A FANTASTIC TRANSITION

FROM LAND TO AIR.

MODERN MAMMALS EVOLVING
FROM TINY RODENT-LIKE CREATURES.

AND FROM THE BRANCH OF MAMMALS, OUR OWN STORY BEGAN.

AND WE CONTINUE TO EVOLVE ALONG WITH ANCIENT MICROBIAL FORMS,

SOME OF THOSE QUITE COMPLEX

THAT STILL PERSIST
AND THRIVE TODAY.

THE STORIES OF
ANY ONE BRANCH OR LINEAGE

SPAN AN IMMENSE AMOUNT OF TIME.

THEY ARE STORIES
WITH MANY GAPS

AS WELL AS DETAILS THAT CHANGE

AS NEW EVIDENCE EMERGES.

IT'S BEYOND THE SCOPE
OF THIS SERIES

TO ANSWER ALL THE QUESTIONS

THAT NECESSARILY ARISE
ABOUT EVOLUTION.

OUR GOAL IS TO CONTINUE
TO LOOK AT EVOLUTION

AS A RESILIENT THEORY

TO ACCOUNT FOR THE DIVERSITY
OF SPECIES ON EARTH.

LET'S START TODAY'S SESSION

BY ASKING A QUESTION THAT MANY OF OUR STUDENTS MIGHT ASK.

WHY ARE THERE SO MANY DIFFERENT TYPES OF LIVING THINGS?

WE'LL JOIN ELEANOR ABRAMS
IN THE SCIENCE STUDIO

TO LISTEN TO
THE CHILDREN'S IDEAS

ABOUT THE MEANING OF SPECIES.

SEE HOW THEIR IDEAS COMPARE
TO YOUR OWN.

JUST WHAT IS A SPECIES?

SPECIES PROBABLY GOES WITH, LIKE, DIFFERENT KINDS OF THINGS.

LIKE, ALL THE TORTOISES
GO OVER HERE.

AND THESE SNAKES GO HERE.

AND THIS GOES HERE.

AND THAT GOES OVER HERE
AND THIS GOES OVER HERE.

AND THESE ARE, LIKE,
ALL THE CATEGORIES

AND ALL THE SPECIES.

Boy: SPECIES, WELL, THAT
CAN BE EASILY EXPLAINED.

SPECIES, SPECIES,
SPECIES.

AND SPECIES.

REPTILES, REPTILES,
AMPHIBIANS.

NO, THOSE
ARE ALSO REPTILES.

THESE ARE --
THIS IS AMPHIBIANS

AND THIS IS REPTILES.

BUT YOU CAN GO EVEN DEEPER.

THESE ARE TURTLES, THESE
ARE SNAKES, LIZARDS,

GECKO.
AND FROGS.

BUT IF YOU
GO EVEN DEEPER,

THESE TURTLES
AND TORTOISES,

THEY'RE PROBABLY
ALL DIFFERENT KINDS.

EXCEPT FOR,
I THINK, THESE.

YEAH.

WELL, A SPECIES
IS JUST A TYPE

OR A, UH,

PART OF
THE ANIMAL KINGDOM.

OR IT DOESN'T EVEN
HAVE TO BE AN ANIMAL

BECAUSE WE'RE
A SPECIES OF PERSON.

BUT NOT LIKE THERE'S ANY
OTHER SPECIES OF PERSON,

BUT WE'RE A SPECIES BECAUSE ORIGINALLY WE WERE ANIMALS.

ANY LIVING THING.

YEAH, ANY LIVING THING
IS PART OF A SPECIES.

Narrator: THE CHILDREN SEEM
TO UNDERSTAND THAT SPECIES

IS A WAY OF GROUPING ANIMALS.

DIFFERENT TEAMS
HAD DIFFERENT IDEAS

ABOUT HOW BROADLY OR NARROWLY
TO DEFINE THESE GROUPS.

ALL TURTLES AS ONE SPECIES,
FOR EXAMPLE,

OR DIFFERENT LOOKING TURTLES
AS DIFFERENT SPECIES.

THIS RAISED A NEW QUESTION.

HOW DID YOU FIGURE OUT THAT
THEY WERE ALL THE SAME ANIMALS?

BECAUSE THEY ALL
LOOKED LIKE --

THEY HAVE, LIKE,
THE SAME SHAPES

EVEN THOUGH IT'S
NOT THE SAME COLOR.

AND THEY ALL, LIKE, LOOK
THE SAME, NOT COLOR-WISE.

BUT, YEAH,
THEY JUST LOOK THE SAME.

AND THESE ARE -- YOU KNOW
THAT THESE ARE FROGS.

YOU KNOW THESE ARE TURTLES,
YOU KNOW THESE ARE SNAKES,

AND YOU KNOW THIS IS
A LIZARD, THAT'S WHY.

OH, BECAUSE THEY'RE
ALL POISONOUS.

YOU KNOW I USED
THE COLOR AND THESE?

WELL, IN A WAY
THAT WASN'T CORRECT.

BECAUSE THESE ARE
ALL DIFFERENT COLORS

AND THEY'RE PROBABLY
THE SAME SPECIES.

SO SPECIES ARE
DETERMINED BY GENES

AND, UH,
IMPORTANT FEATURES.

LIKE, THIS IS
A SNAPPING TURTLE

AND YOU CAN TELL
THAT BECAUSE --
SNAPPING TURTLE?

SNAPPING -- BECAUSE IT
HAS A BLUNT NOSE

AND IT HAS THESE, LIKE,
SPIKY THINGS.

AND THIS IS
A SEA TURTLE.

BECAUSE IT
HAS FLIPPERS.

BECAUSE IT HAS FLIPPERS
INSTEAD OF, LIKE, FEET

THAT YOU CAN SEE.

AND --

THIS IS A BOX TURTLE
BECAUSE IT HAS BOXES.

YEAH, NO.

Narrator: ALL OF THE CHILDREN RELIED ON VISUAL CLUES

TO SORT THE ANIMALS INTO GROUPS.

AND GREG THOUGHT THAT HIDDEN FEATURES SUCH AS GENES

MIGHT BE PART OF WHAT
DETERMINES A SPECIES.

WE NEXT ASKED THE CHILDREN
TO THINK ABOUT

SPECIES AND REPRODUCTION,

WHICH ANIMALS CAN AND CANNOT HAVE OFFSPRING TOGETHER.

DO YOU THINK THAT
THOSE TWO SNAKES

THAT YOUR HANDS ARE ON,

DO YOU THINK THAT THOSE TWO COULD REPRODUCE TOGETHER

AND HAVE BABY
SNAKES TOGETHER?

UM, I DON'T THINK SO.

BECAUSE I THINK YOU NEED,
LIKE -- OH, WAIT.

I DON'T THINK THIS IS
THE SAME SPECIES.

BECAUSE THEY ARE SNAKES,
BUT THEY HAVE DIFFERENT KINDS,

LIKE COBRA AND STUFF, PYTHONS.

SO, NO, I DON'T THINK
THEY CAN HAVE BABIES.

THEY NEED, LIKE --
IF THIS, LIKE,

IS A COBRA, THEY NEED ANOTHER COBRA TO HAVE, LIKE A BABY.

COULD THESE TWO TURTLES
GET TOGETHER

IF THERE WAS A MALE
AND FEMALE AND REPRODUCE?

PROBABLY.
I THINK THEY COULD.

THEY'D PRODUCE
A CROSSBREED.

YEAH.

NOT LIKE HUMANS
AND FROGS, THOUGH.

NO, I DON'T THINK
THAT COULD HAPPEN.

BUT I THINK A TURTLE
AND A DIFFERENT TURTLE.

A SNAKE -- YEAH.

THAT WOULD BE STRANGE.

WELL, IT'S STRANGE, LIKE
A YAK AND AN OSTRICH.

YEAH, IT'S POSSIBLE.

I THINK IT IS
POSSIBLE, THOUGH.

BECAUSE I'VE HEARD
THAT A LION AND A TIGER

COULD ALSO REPRODUCE.

BUT THERE ISN'T
MUCH DIFFERENCE.

THEY'RE BOTH CATS
IN GENERAL,

BUT THERE IS A DIFFERENCE.

Woman: BUT COULD A TURTLE
AND A FROG REPRODUCE TOGETHER?

I DOUBT IT.

IN THE WILD?

IN THE WILD, NO,
THEY WOULDN'T.

MOST LIKELY
THEY WOULD NOT.

WELL, IN THE WILD BECAUSE
THEY'D NEVER, LIKE, UM,

BE IN THE SAME PLACE.

IT WOULD BE A VERY,
VERY UNLIKELY CHANCE.

PLUS TURTLES EAT FROGS.

ALL THE CHILDREN USED
EXTERNAL APPEARANCE

AS THEIR MAIN STRATEGY
FOR CLASSIFYING GROUPS,

ALTHOUGH THEY DIFFERED ON HOW BROADLY THEY DEFINED SPECIES.

THE QUESTION ABOUT REPRODUCTION WAS A PUZZLE TO THE CHILDREN.

P.J. AND MICHAEL, FOR EXAMPLE,

THOUGHT DIFFERENT SPECIES
COULD INTERBREED

AS LONG AS THEY WEREN'T
TOO DIFFERENT.

THE CHILDREN'S SEARCH
FOR ANSWERS

HAS SET US UP BEAUTIFULLY

FOR AN EXPLORATION OF
A DEFINITION OF SPECIES.

BECAUSE IT TURNS OUT

THAT THE EVIDENCE
USED TO CLASSIFY SPECIES

HAS CHANGED
OVER THE LAST CENTURY.

AND EVEN TODAY
IT'S STILL CHANGING.

TAKE BEETLES, FOR EXAMPLE.

HOW MANY SPECIES OF BEETLES

DO YOU THINK THERE ARE
IN THE WORLD?

5,000, 10,000?

Grisham: SOME ESTIMATES PUT
THE NUMBER HIGHER THAN 350,000.

AND THAT NUMBER
IS ACTUALLY RISING

AS WE DISCOVERED HABITATS
PREVIOUSLY INACCESSIBLE TO US.

SUCH AS A RAINFOREST CANOPIES.

Narrator: DR. JIM HANKEN

IS THE CURATOR OF THE REPTILE
AND AMPHIBIAN COLLECTION

OF HARVARD'S MUSEUM
OF COMPARATIVE ZOOLOGY.

FOR HIM, THIS IS
A EXCITING TIME OF DISCOVERY,

A CONTINUATION OF
A RICH TRADITION

THAT DATES BACK
TO THE 19th CENTURY.

Hanken: WELL, THIS WAS VERY
MUCH IN THE AGE OF EXPLORATION,

WHEN COUNTRIES WERE SENDING OUT NAVIGATORS AND EXPLORERS

ALL OVER THE WORLD.

AND THEY WERE BRINGING BACK FROM THE FOUR CORNERS OF THE GLOBE

ALL KINDS OF BIZARRE, HERETOFORE NEVER SEEN PLANTS AND ANIMALS.

AND MUSEUMS ARE WHERE
THEY WERE PUT.

Narrator: THE COLLECTION GREW.

AND NATURALISTS DEVELOPED
A BETTER AND BETTER EYE

FOR FINE DETAIL.

PUZZLES BEGAN
TO PRESENT THEMSELVES

IN THE FORM OF CONTRADICTIONS.

LIZARDS AND SNAKES, FOR EXAMPLE.

WE'RE ALL FAMILIAR

WITH THESE DISTINCT LOOKING GROUPS OF REPTILES.

SO IT SHOULD BE EASY

TO SEPARATE SPECIES
INTO ONE GROUP OR THE OTHER.

BUT IS IT?

HERE WE'VE GOT FOUR DIFFERENT SETS OF SPECIMENS,

A LIZARD AND A SNAKE.

AND THESE OTHERS ARE ALSO
LIZARDS AND SNAKES

BUT NOT QUITE
AS YOU'D EXPECT THEM.

SO LET ME JUST SHOW YOU
WHAT WE'VE GOT HERE.

THIS IS A LIZARD.

IT'S A VERY UNUSUAL LIZARD,
BUT A LIZARD NONETHELESS.

IT'S A CHAMELEON FROM AFRICA.

AND YOU CAN SEE --

I'M GOING TO SET IT DOWN HERE
ON THE TRAY --

YOU CAN SEE THAT IT'S GOT

THE CHARACTERISTIC SCALES
OF A LIZARD.

AND IT HAS FOUR
WELL-DEVELOPED LIMBS.

AND IT'S IN GENERAL,

ALTHOUGH IT HAS SOME VERY UNUSUAL CHAMELEON FEATURE,

IT'S NONETHELESS
VERY LIZARD-LIKE.

THIS IS A KING SNAKE,

WHICH IS A SPECIES FOUND
IN NORTH AMERICA.

THERE ARE SEVERAL SPECIES
FOUND IN NORTH AMERICA.

AND IT IS COMPLETELY LIMBLESS.

THERE'S REALLY NO PROBLEM TELLING THIS LIZARD

APART FROM THIS SNAKE.

THIS IS A BOA CONSTRICTOR.

A VERY LARGE SNAKE,

ALTHOUGH NOT VERY LARGE AS
BOA CONSTRICTORS GO.

THIS ONE IS ABOUT

FOUR FEET TOTAL LENGTH.

AND IT'S VERY SNAKE-LIKE,
OF COURSE.

UNMISTAKABLE FOR A SNAKE
UNTIL YOU LOOK CAREFULLY

AT THE UNDERSIDE OF THE BODY, DOWN AT THE BASE OF THE TAIL.

AND RIGHT THERE ON ONE SIDE
AND THEN ON THE OTHER,

THIS IS A VESTIGE
OF THE HIND LIMB.

THESE ARE REPTILES,
THEY HAVE SCALES

JUST LIKE THE SNAKE
AND THE LIZARD DO.

THEY HAVE ELONGATE TAIL, ELONGATE HEAD.

AND I THINK MOST
PEOPLE WOULD SAY

THIS IS PROBABLY ANOTHER SNAKE.

IN FACT, THAT'S NOT THE CASE, THIS IS A LIZARD.

IT'S A KIND OF LIZARD
THAT LACKS LIMBS.

WE KNOW FOR A FACT,
UNMISTAKABLY IT'S A LIZARD

BECAUSE IT TURNS OUT
SNAKES AND LIZARDS

HAVE VERY DIFFERENT SKULLS.

Narrator: DR. HANKEN'S SNAKES WITH LIMB SPURS

AND LIMBLESS LIZARDS
RAISE QUESTIONS

ABOUT USING WHAT SEEMED TO BE THE MOST OBVIOUS DIFFERENCES

TO PLACE ORGANISMS
INTO GROUPS OF SPECIES.

CLASSIFICATION
INTO SPECIES GROUP

RELIES ON FEATURES
THAT ARE SHARED

ONLY BY MEMBERS OF THAT GROUP.

IN THIS CASE, SKULLS ARE ONE DIAGNOSTIC FEATURE.

SNAKES HAVE HIGHLY MOBILE JAWS

THAT CAN OPEN WIDE ENOUGH TO SWALLOW VERY LARGE PREY.

LIZARDS' JAWS ARE NOT STRUCTURED TO ALLOW THIS.

WHAT ABOUT SPECIES THAT LOOK ALMOST IDENTICAL?

COLLECTORS EVENTUALLY REALIZED

THAT STUDYING ANIMALS
IN THE FIELD

OFTEN YIELDED
MUCH BETTER EVIDENCE

FOR CLASSIFICATION INTO SPECIES.

Hanken: WHEN PEOPLE WENT OUT
IN NATURE, THEY FOUND THAT

WHAT PEOPLE HAD REGARDED UNTIL THEN AS THE SAME SPECIES

IN FACT CONSISTED
OF DIFFERENT SPECIES

BECAUSE THEY STARTED
USING BEHAVIOR,

IN THE CASE OF ANIMALS,

GEOGRAPHIC VARIATION
AND SO FORTH

AS DIFFERENT FEATURES
INTO WHICH TO SEGREGATE SPECIES.

SO FOR INSTANCE,
A SPECIES WAS REGARDED AS

A GROUP OF INTERBREEDING INDIVIDUALS.

ACTUALLY OR POTENTIALLY INTERBREEDING INDIVIDUAL.

USING THE CRITERION
OF THE ABILITY TO INTERBREED,

ORGANISMS INITIALLY CLASSIFIED INTO ONE SPECIES

WERE ULTIMATELY GROUPED
INTO TWO OR MORE.

MANY SPECIES OF ANIMALS

HAVE BEEN ADDED TO THE TREE
OF LIFE IN THIS WAY.

DR. HANKEN STUDIES A GROUP OF AMPHIBIANS CALLED SALAMANDERS.

HIS WORK HAS DIVIDED

WHAT WAS CONSIDERED
A FEW SPECIES INTO MANY.

Hanken:
I WORK ON A GROUP OF SALAMANDERS

THAT'S FOUND ONLY
IN SOUTHERN MEXICO.

THESE ARE THE SMALLEST TERRESTRIAL VERTEBRATES.

THEY'RE VERY TINY,
THEY'RE ABOUT THIS LONG,

INCLUDING THE TAIL, AS ADULTS.

AND THEY LIVE UNDER LOGS,
UNDER BARK.

THEY'RE VERY SECRETIVE,
THEY'RE UNASSUMING.

THEY DON'T MAKE A CALL.

WE FIND SEVERAL PLACES

WHERE THERE ARE AT LEAST
THREE SPECIES CO-EXISTING,

JUST LYING NEXT TO ONE ANOTHER.

WE HAVE NO EVIDENCE WHATSOEVER THAT THEY'RE INTERBREEDING.

WE TAKE THE ANIMALS
AND WE LOOK AT THEIR ANATOMY.

WE LOOK AT THEM EXTERNALLY,
LOOK AT THEIR COLOR.

WE LOOK AT THE HEAD SHAPE, WE LOOK AT THE SIZE OF THEIR FEET

AND RELATIVE LENGTH OF THE TAIL.

BUT WE ALSO LOOK AT
THE SKELETONS INSIDE THE BODY.

BUT WE ALSO LOOK
AT THEIR DNA SEQUENCES.

THEY'RE NOT DIFFERENT
ENOUGH ANATOMICALLY

TO TIP YOU OFF THAT YOU HAVE MORE THAN ONE SPECIES

AT A GIVEN PLACE.

BUT AS SOON AS YOU LOOK AT THEM BIOCHEMICALLY

OR WITH MOLECULAR COMPARISONS,

IT'S CLEAR CUT,
IT'S NIGHT AND DAY.

WHEN I STARTED MY WORK THERE WERE, LET'S SAY 10 SPECIES,

VALID SPECIES NAMED --
THIS WAS IN THE 1970s.

AND NOW THERE ARE 24.

WE'VE DESCRIBED ANOTHER 14.

AND WE KNOW OF AT LEAST
EIGHT MORE UNDESCRIBED

THAT WE STILL HAVE TO DO
THE WORK THAT WILL ULTIMATELY

RESULT IN THEM HAVING NAMES
AND ALL.

AND I HAVE NO DOUBT THERE'S STILL MORE DOWN THERE.

SO THE TOTAL COUNT WILL BE SOMEWHERE IN THE 30s.

AT LEAST 30 SPECIES OR MORE.

YOU CAN SEE THAT THE ANSWER
TO THE QUESTION,

"WHAT IS A SPECIES?" ISN'T
AS OBVIOUS AS WE ONCE THOUGHT.

LOOKS CAN BE DECEIVING.

BUT THE MORE INFORMATION
WE HAVE,

THE MORE CONFIDENT WE CAN BE
IN CLASSIFYING SPECIES.

TODAY THE MOST
COMMONLY APPLIED CRITERION

FOR ANIMALS AND OTHER SEXUALLY REPRODUCING LIFE FORMS

IS THAT THEY CAN PRODUCE FERTILE OFFSPRING TOGETHER.

THIS INTERBREEDING CREATES
A DISTINCT GENETIC IDENTITY

FOR THE MEMBERS OF A SPECIES.

EACH SPECIES
HAS A UNIQUE GENOME.

BUT IT'S TRICKY WITH ASEXUALLY REPRODUCING LIFE FORMS.

LIKE MINI MICROBES, FOR EXAMPLE.

INTERBREEDING CAN'T BE USED
AS A CRITERION.

BUT THIS IS WHERE DNA SEQUENCING IS REALLY MAKING HEADWAY.

TO FIND OUT MORE ABOUT
HOW DNA SEQUENCING

IS HELPING WITH
THE IDENTIFICATION OF SPECIES,

PLEASE VISIT OUR WEBSITE.

IN MANY CASES
WE CAN TELL THE DIFFERENCE

BETWEEN SPECIES ON SIGHT.

NO ONE IS ABOUT TO CONFUSE
A DOMESTIC DOG WITH A HOUSE CAT.

OR THIS BIRD OF PARADISE
WITH THIS CANADA GOOSE.

AND THAT BRINGS US
TO OUR CENTRAL QUESTION.

WHY ARE THERE SO MANY SPECIES?

WE KNOW FROM
THE FOSSIL RECORD

THAT THE KIND OF SPECIES
ON EARTH HAVE CHANGED

DURING EVOLUTIONARY HISTORY.

WHEN ASKED HOW NEW SPECIES
MIGHT COME INTO BEING,

THE CHILDREN IN THE SCIENCE STUDIO HAD NO SHORTAGE OF IDEAS.

HOW DO NEW SPECIES EVOLVE?

Grisham:
WE ASKED THE CHILDREN TO TELL US

WHAT THEY KNEW ABOUT EVOLUTION AND ADAPTATION.

ALL RIGHT, EVOLUTION IS,

UH, WHEN A SPECIES
CHANGES OVER THE YEARS,

WHEN IT'S GENES CHANGE DUE
TO THE ENVIRONMENT CHANGE.

OR MAYBE WHAT THIS NEW THING THAT THEY'RE TRYING.

SAY THE SEA TURTLE,
THIS IS ITS FIRST STAGE,

AND IT WANTED TO GO
OUT OF THE WATER,

SO IT STARTED DOING THAT
WITH ITS FLIPPERS.

AND OVER THE YEARS
THEY STARTED ADAPTING.

AND THEY GOT FLAT,

REGULAR, UM, FEET.

SO THEY COULD WALK ON LAND
AND GO IN THE WATER.

HOW ABOUT ADAPTATION?

ADAPTATION IS PRETTY MUCH
THE SAME AS EVOLUTION.

EXCEPT IT'S WHEN YOU
GET USED TO A PLACE.

IT'S WHEN YOU GET USED
TO A CLIMATE OR, OR --

AREA THAT IS DIFFERENT
FROM YOUR --

LIKE, SAY THIS TURTLE,
UM, THIS TURTLE

THIS TURTLE LIVED
IN THE OCEAN OR THE SEA

BECAUSE IT'S
A SEA TURTLE.

LIKE GREG WAS SAYING,
IF IT CAME ON LAND

AND STARTED TO BE
A LAND TURTLE,

THEN IT WOULD ADAPT
TO THE SANDY

OR, UM, DIRTY CLIMATE

INSTEAD OF THE WET,

THE WET CLIMATE
IN THE WATER.

SO IT WOULD HAVE
TO ADAPT TO ITS CLIMATE.

EVOLUTION IS REALLY
WHEN SOMETHING

STARTS OUT ONE WAY AND JUST
GROWS INTO ANOTHER.

LIKE HUMANS EVOLVED,
THEY DIDN'T ADAPT.

AND ADAPTATION IS
THE PROCESS OF EVOLUTION.

LIKE, LIKE I SAID,

IF THESE FROG SPECIES
SLOWLY MOVED OVER HERE,

AND KEPT ON GOING,

OVER A LONG PERIOD OF TIME,

IT WOULD ADAPT
TO THE CLIMATE.

Narrator: NEXT WE ASKED
THE CHILDREN HOW THEY THOUGHT

NEW SPECIES MIGHT ARISE.

A SPECIES IS
USUALLY DETERMINED

BY ADAPTATION
SOMETIMES.

BECAUSE THIS COULD BE
THE ORIGINAL STATE

OF ONE OF THE FIRST
SPECIES OF TURTLE.

THEN THEY STARTED
MOVING TO OTHER CLIMATES,

AND THEY BECAME
MORE LIKE THIS.

AND THAT'S
A DIFFERENT SPECIES.

THEY STILL HAVE
THIS SPECIES,

BUT THERE STARTS TO
GROW MORE SPECIES.

Woman: HOW DID
THAT HAPPEN?

BECAUSE IT ADAPTED TO
A DIFFERENT CLIMATE.

LIKE HE WAS SAYING BEFORE,

IF THIS SEA TURTLE CAME
AND STARTED TO LIVE ON LAND,

THEN IT WOULD CHANGE.

IT WOULD TURN
INTO THAT ONE.

WHAT, INTO THIS ONE
OR THIS ONE?

AND I GUESS IT'S ABOUT "ADVENTUROUS" ANIMALS

IN A WAY.

BECAUSE I BET ANIMALS
ARE INTELLIGENT ENOUGH

TO KNOW WHAT'S SAFE
AND WHAT'S NOT.

AND I BET ONE
TURTLE THOUGHT --

OR, UM, SOMETHING THAT,

THAT IF THEY MOVED
TO A NEW LAND,

THEY COULD HAVE BEEN SAFER
FROM THEIR PREDATORS

THAT THEY HAD
AT ONE TIME.

AND AS SOON AS THEY
GOT OUT THERE --

WELL, NOT AS SOON,

BUT WHEN THEY GOT
OUT THERE,

THEY STARTED TO ADAPT
AND THEY STARTED TO BECOME

MORE LAND-LIKE
INSTEAD OF LIKE THESE.

THIS TABLE IS -- LET'S
PRETEND IT'S PLANET EARTH.

THIS TURTLE IS A SPECIES,

AND THIS TURTLE HASN'T
BEEN CREATED YET.

WE'LL PUT HIM
OFF TO THE SIDE.

OKAY, HE MOVES HERE
A LITTLE --

THE SPECIES MOVES A LITTLE
AND KEEPS ON GOING.

LET'S SAY THIS IS
THE FOREST, THE JUNGLE.

LET'S JUST SAY
HE'S HERE ALREADY.

YEAH, OKAY,
HE TOOK A PLANE.

HE NEEDED TO CAMOUFLAGE IN

AS IT GOT SLOWLY MORE
INTO GREEN FOREST.

YEAH, THERE ARE
MORE PREDATORS.

AND EVENTUALLY
THE SPECIES TURNED GREEN.

THIS ONE HAD TO MOVE
TO A VERY MUDDY AREA.

SO IT KEEPS ON GOING
AND GOING AND GOING,

UNTIL IT EVENTUALLY ADAPTS
TO WHAT IT IS NOW.

AND THIS ONE WOULD GO
TO A DESERT-ISH AREA.

I DON'T THINK IT
WOULD BE DESERT.

PROBABLY, I'D SAY

THOSE COLORS WOULD BE
FOR WARNING.

SAY THEY MOVED TO AN AREA

WITH A LOT OF PREDATORS

AND THEY BECAME POISONOUS
OVER MILLIONS OF YEARS.

Woman: COULD THEY DO IT
OVER ONE LIFETIME?

NO, IT WOULD TAKE MANY, MANY, MANY, MANY, MANY LIFETIMES.

IT WOULD TAKE, LIKE,
MILLIONS OF YEARS.

THE CHILDREN BELIEVE
THAT NEW SPECIES CAN EMERGE

IN RESPONSE TO
DIFFERENT ENVIRONMENTS.

AND THEY BELIEVE IT CAN
TAKE MILLIONS OF YEARS

FOR THAT PROCESS TO OCCUR.

THEY ALSO THINK THAT ONE SPECIES CAN ARISE FROM ANOTHER.

WHICH SUGGESTS THAT THEY BELIEVE THAT DIFFERENT SPECIES

CAN SHARE A COMMON ANCESTOR.

THEIR IDEAS ABOUT THE MECHANISMS THAT CREATE NEW SPECIES

ARE NOT YET
SCIENTIFICALLY ACCURATE.

IN THE PREVIOUS SESSION, WE EXPLORED HOW EXISTING VARIATION

WITHIN A POPULATION
MAKES CERTAIN INDIVIDUALS

FIT BETTER INTO
THEIR ENVIRONMENT.

THESE INDIVIDUAL SURVIVE BETTER

AND PRODUCE MORE OFFSPRING.

AND OVER MANY GENERATIONS,

THE VARIATION
BECOMES MORE COMMON.

THIS IS ADAPTATION
THROUGH NATURAL SELECTION.

AND THE RESULT,
AT LEAST AT FIRST,

IS EVOLUTION WITHIN A SPECIES.

HOW DOES THE SAME PROCESS RESULT IN AN ENTIRELY NEW SPECIES,

POPULATIONS OF ANIMALS,
FOR EXAMPLE,

THAT CAN NO LONGER INTERBREED?

TO GET A BETTER UNDERSTANDING
OF HOW WE THINK

NEW SPECIES ARISE
THROUGH EVOLUTION,

WE'LL LOOK AT A CLASSIC EXAMPLE FROM DARWIN'S EXPEDITION

ON THE *HMS BEAGLE*.

Narrator: DURING DARWIN'S HISTORIC VOYAGE IN THE 1830s,

HE VISITED
THE GALAPAGOS ISLANDS,

A REMOTE GROUP OF RELATIVELY YOUNG VOLCANIC ISLANDS

THAT HAVE SINCE
BECOME A LIVING LABORATORY

FOR BUILDING THE THEORY
OF EVOLUTION.

SOME OF HIS MOST
IMPORTANT INSIGHTS

CAME FROM HIS STUDIES
OF BIRD POPULATIONS

THAT INHABIT EACH
OF THESE ISLANDS,

BIRDS THAT ARE NICKNAMED DARWIN'S FINCHES.

THIS GROUP OF BIRDS HERE COLLECTIVELY

IS KNOWN AS DARWIN FINCHES.

THESE REPRESENT THE TYPES OF BIRDS THAT DARWIN SAW

WHEN HE FIRST CAME
TO THE GALAPAGOS ISLANDS.

THE GALAPAGOS ISLANDS ARE FAR OFF THE COAST OF SOUTH AMERICA,

RIGHT ON THE EQUATOR.

THEY ARE VERY
FORBIDDING LOOKING.

AND TO DARWIN'S EYES AND TO MANY PEOPLE WHO CAME AFTER HIM,

THEY ARE VERY SIMILAR
IN APPEARANCE.

AND SO HERE WAS A CONUNDRUM.

HOW COULD THERE BE SO
MANY DIFFERENT

TYPES OF BIRDS AND FORMS

ON ISLANDS THAT WERE SO SIMILAR?

DARWIN HAD A PROBLEM WITH THIS.

HE CERTAINLY UNDERSTOOD HOW SPECIES CAN POPULATE AN ISLAND.

A LONG DISTANCE MIGRATION.

BUT HE WAS UNABLE TO EXPLAIN

HOW THERE COULD BE SO MANY
FORMS GENERATED.

THERE SHOULD NOT BE THIS ENORMOUS AMOUNT OF VARIATION

FOR WHAT APPEARED TO BE
CONSTANT ENVIRONMENTS

WITH THE SAME SELECTION OF FOOD.

Narrator: DARWIN'S CONUNDRUM WAS BUILT UPON THE IDEA

THAT IF A POPULATION OF FINCHES FROM THE MAINLAND

DISPERSED TO ISLANDS
THAT REPRESENTED

ESSENTIALLY THE SAME ENVIRONMENT,

THE RESULTING POPULATIONS
MIGHT CHANGE TO BE DISTINCT

FROM THE MAINLAND SPECIES

BUT NOT ENOUGH TO BE DIFFERENT FROM EACH OTHER.

IN OTHER WORDS, ONE NEW ENVIRONMENT, ONE NEW SPECIES.

THIS WASN'T THE CASE.

EACH ISLAND BOASTED
DIFFERENT SPECIES

WITH A WIDE RANGE
OF FEATURES THAT VARIED.

DARWIN WAS LEFT WITH A PUZZLE.

HOW COULD THIS OCCUR?

Causey: OUR UNDERSTANDING NOW
BUILDS ON WHAT

DARWIN OBSERVED AND SURMISED.

A SMALL GROUP OF BIRDS PROBABLY 1 TO 2 MILLION YEARS AGO

BLOWN OFF COURSE PERHAPS

ARRIVED TO THE GALAPAGOS,

BIRDS THAT LOOKED VERY SIMILAR TO THIS SPECIES HERE.

THEY BECAME A RESIDENT
ON ONE OF THE ISLANDS.

WE DON'T KNOW WHICH ONE.

AND THEN THROUGH TIME,

THESE BIRDS DISPERSED
TO ANOTHER ISLAND.

AND ALTHOUGH DARWIN THOUGHT THAT THEY WERE VERY SIMILAR,

AND CERTAINLY SUCCEEDING NATURALISTS DID, TOO,

CLOSER EXAMINATION SHOWS THAT EACH ISLAND IN THE GALAPAGOS

HAS A DIFFERENT
SELECTION OF PLANTS,

A DIFFERENT MICROCLIMATE.

IN FACT, THEY ARE NOT AS SIMILAR AS WHAT DARWIN THOUGHT.

THIS GROUP OF BIRDS WHICH CAME FROM THE FIRST ISLAND

AND WENT TO THE SECOND,
IT EXPERIENCED

DIFFERENT CONDITIONS THAT WERE ON THE INITIAL ISLAND.

THIS REPEATED CYCLE
OF DISPERSAL,

ISOLATION BY DISTANCE,

AND THEN RETURN AND COMPETITION

IS ONE OF THE EXPLANATIONS OF WHY THERE IS SO MUCH VARIATION,

WHY THERE IS SO MANY DIFFERENT FORMS OF BIRDS ON THE GALAPAGOS.

THIS IS A GOOD EXAMPLE OF ONE WAY THAT NEW SPECIES ARRIVE,

GEOGRAPHIC ISOLATION.

A POPULATION CAN BECOME SEPARATED FROM ANOTHER

WHERE THE NEW ENVIRONMENT IS DIFFERENT FROM THE OLD.

EXISTING VARIATION FAVORS CERTAIN INDIVIDUALS

WHO HAPPEN TO HAVE FEATURES
THAT ENABLE THEM TO SURVIVE

IN THAT PARTICULAR ENVIRONMENT.

THEY LEAVE MORE OFFSPRING.

THEREFORE, OVER TIME,

THESE VARIANTS
BECOME MORE COMMON,

ADAPTATION THROUGH NATURAL SELECTION OCCURS,

AND THE POPULATION EVOLVES.

WITH THE FINCHES,

THIS HAPPENED CONCURRENTLY
ON MANY ISLANDS.

Grisham: THIS ACCOUNTS
FOR POPULATIONS THAT DIFFER

FROM AN ORIGINATING POPULATION.

BUT HOW DOES THIS RESULT
IN AN ENTIRELY NEW SPECIES?

AS A POPULATION EVOLVES,

MANY THINGS CAN CHANGE.

AND AT SOME POINT,

AT LEAST IN SEXUALLY
REPRODUCING SPECIES,

THE ABILITY TO INTERBREED
WITHIN THE ORIGINAL POPULATION

IS LOST.

THIS IS WHAT CLASSIFIED
EACH FINCH POPULATION

AS A NEW SPECIES.

WELL, LET'S INVESTIGATE
ANOTHER EXAMPLE,

THE EVOLUTION
OF THE MODERN HORSE.

THINK ABOUT HOW
VARIATION AND ADAPTATION

THROUGH NATURAL SELECTION MIGHT HAVE WORKED IN THIS CASE.

Narrator: AN ANIMAL BELIEVED
TO BE THE EARLY ANCESTOR

OF THE MODERN HORSE
APPEARS IN THE FOSSIL RECORD

ABOUT 60 MILLION YEARS AGO,

BEARING LITTLE RESEMBLANCE
TO THE HORSE WE KNOW TODAY.

CALLED EOHIPPUS,
IT WAS THE SIZE OF A DOG.

IT WEIGHED ABOUT 12 POUNDS
AND HAD A HEAD AND BODY

THAT RESEMBLED THAT
OF A SMALL DEER.

FOSSILS OF MANY OTHER ANCIENT HORSE SPECIES,

HAVE ALSO BEEN
DISCOVERED TOGETHER.

MOST OF THESE ARE NOW EXTINCT,

BUT SOME OF THEM PLAYED A ROLE IN THE SLOW TRANSITION,

OVER MILLIONS OF YEARS,

FROM EOHIPPUS TO MODERN SPECIES IN THE GROUP CALLED EQUES.

INCLUDING THE HORSE
WE KNOW TODAY.

WHY ARE WE LEFT WITH
VERY FEW SPECIES OF HORSE

BUT MANY SPECIES OF FINCH?

Hanken: IN SOME CASES
THE REASONS FOR EXTINCTION

ARE VERY STRAIGHTFORWARD.

EITHER THE HABITAT
JUST DISAPPEARED

OR IT GOT BELOW
A CERTAIN LEVEL

WHERE IT COULD SUSTAIN
A POPULATION

OF A MINIMUM SIZE REQUIRED
FOR PERPETUATING THE SPECIES.

IN OTHER CASES, THERE MAY BE COMPETING SPECIES THAT AROSE

AND THAT ARE VERY SIMILAR

IN TERMS OF
THEIR WAY OF LIFE,

IN TERMS OF THE FOODS
THAT THEY EAT,

THE PLACES THAT THEY OCCUPY

AND HAVE SOME ADVAN --

THIS IS THE CLASSIC SURVIVAL
OF THE FITTEST KIND OF A THING.

THAT SOME NEW FEATURE,
A NEW ADAPTATION,

EVOLVES IN ONE GROUP
AND NOT ANOTHER,

AND ALLOWS THAT GROUP THAT HAS

TO MORE EFFECTIVELY
UTILIZE THE RESOURCES

AND OUT-COMPETE
THE OTHER SPECIES.

SURVIVAL OF THE FITTEST IMPLIES

THAT MANY OF
NATURE'S EXPERIMENTS

ARE NOT GOING TO SUCCEED.

BUT DESPITE EXTINCTIONS,

EVOLUTION PREDICTS THAT
THE EXPERIMENTS WILL CONTINUE

AND THAT THERE WILL BE SOME
VERY INGENIOUS SOLUTIONS

TO THE PROBLEM OF SURVIVAL
AT THE SPECIES LEVEL.

LAST SESSION
WE INTRODUCED SYMBIOSIS,

AN INTIMATE ASSOCIATION
BETWEEN TWO OR MORE SPECIES.

LICHENS AND CORALS, FOR EXAMPLE.

SYMBIOSIS IS ONE OF THOSE INGENIOUS SOLUTIONS

THAT CAN LEAD TO THE EVOLUTION OF AN ENTIRELY NEW SPECIES.

Zook: IN THE 1960s,
DR. KWANG JEON

AT THE UNIVERSITY OF TENNESSEE

WAS CULTURING AMOEBA
IN HIS LABORATORY.

THESE AMOEBA BECAME
INFECTED BY BACTERIA.

THAT KILLED MOST
OF THE POPULATION.

SOME AMOEBA, HOWEVER, SURVIVED.

AND ACTUALLY BECAME DEPENDENT
ON THEIR INFECTING BACTERIA

AND COULDN'T EVEN SURVIVE WITHOUT THEM.

NOT ONLY THAT, THESE AMOEBA
EVEN DEVELOPED MECHANISMS

TO KILL THE ORIGINAL POPULATION.

UNLIKE EVOLUTION THAT OCCURS OVER MILLIONS OF YEARS

AND HUNDREDS OF THOUSANDS
OF GENERATIONS,

THIS TRANSFORMATION TOOK PLACE IN JUST FIVE YEARS

AND 40 GENERATIONS.

SYMBIOSIS, THEREFORE,
GIVES US AN ADDITIONAL VIEW

OF HOW SPECIES EVOLVE.

LET'S CHECK IN
WITH PAUL WILLIAMS,

OUR BOTTLE BIOLOGIST.

HE'LL BRING US UP TO DATE
ON THE PROGRESS

OF EACH OF OUR FOUR SYSTEMS.

WELCOME BACK TO BOTTLE BIOLOGY.

I HOPE YOU'RE HAVING AS MUCH FUN WITH YOUR SYSTEM

AS WE ARE WITH OURS.

REMEMBER THE MOIST BREAD WE
PUT IN THE TERRAQUA COLUMN?

IS THIS WHAT YOU PREDICT
WOULD HAPPEN?

MOLDS ARE MEMBERS
OF THE FUNGUS KINGDOM.

THEY SECRETE DIGESTIVE CHEMICALS ONTO THEIR FOOD

AND ABSORB
THE NUTRIENT MOLECULES

THROUGH THEIR CELL WALLS.

IN THE BRASSICA AND BUTTERFLY SYSTEM,

WE FINALLY GET A CHANCE TO SEE THE ROLE BUTTERFLIES PLAY

IN THE LIFE CYCLE OF THE PLANT.

WATCH WHAT HAPPENS
AS THE ADULT BUTTERFLIES

FEED ON NECTAR IN THE FLOWERS.

THAT'S POLLEN BEING TRANSFERRED FROM FLOWER TO FLOWER.

NOW IT'S THE BRASSICA'S TURN
TO REPRODUCE.

THIS WEEK WE'RE GOING TO HUNT FOR MICROBES IN THE ECOCOLUMN.

WE'LL USE THESE PLATES FILLED WITH A NUTRIENT MEDIUM

TO SAMPLE THE WATER
AND THE SOIL.

IN FACT, WE'LL TO THIS WITH
THE TERRAQUA COLUMN, TOO.

THE FIELD POPULATION IS FINALLY READY TO GO.

OUR EXPERIMENT WILL INTRODUCE
A VORACIOUS LEAF-EATER.

YOU GUESS IT, THE LARVA OF
THE CABBAGE WHITE BUTTERFLY.

WE'RE TRYING TO FIND OUT WHETHER INDIVIDUAL PLANTS

WITH CERTAIN VARIATIONS
WILL SURVIVE BETTER THAN OTHERS.

TO SET UP YOUR EXPERIMENT,

CHECK OUT BOTTLE BIOLOGY
ON OUR WEB SITE.

THANKS, PAUL.

THE FIELD POPULATION SYSTEM SOUNDS LIKE A GOOD WAY

TO STUDY THE FUNDAMENTALS
OF EVOLUTION.

I'LL BE INTERESTED TO KNOW
WHICH VARIANTS OF PLANTS

WILL SURVIVE BETTER.

THIS ACTIVITY IS A USEFUL WAY

TO INVESTIGATE SURVIVAL
OF THE FITTEST FIRSTHAND.

LET'S TAKE STOCK
OF WHERE WE ARE.

WE'VE LEARNED THAT EACH SPECIES HAS UNIQUE GENETIC IDENTITY,

A UNIQUE GENOME.

IN SEXUALLY REPRODUCING SPECIES,

THIS IDENTITY IS SUSTAINED BY THE INABILITY OF ITS MEMBERS

TO INTERBREED WITH MEMBERS
OF OTHER SPECIES.

Zook: SPECIES ALSO HAVE EVOLUTIONARY HISTORIES,

WHERE ADAPTATION
THROUGH NATURAL SELECTION

HAS RESULTED IN CHANGE
OVER TIME.

NEW SPECIES HAVE EVOLVED
IN THIS MANNER

WITH ONE OR MORE DIVERGING
FROM ONE ANCESTRAL SPECIES.

Grisham: SOMEWHERE OUT THERE,
EACH SPECIES HAS RELATIVES,

SOME CLOSER THAN OTHERS.

HOW CAN WE TELL WHO
IS RELATED TO WHOM?

WHERE DO WE LOOK FOR EVIDENCE?

WELL, WE ASKED
OUR STUDIO SCIENTISTS

TO THINK ABOUT EVOLUTION

AND THE RELATEDNESS OF SPECIES.

SOME OF THEM ARE MORE ALIKE
THAN THEY ARE DIFFERENT.

BUT OTHERS ARE MORE --

YEAH, LIKE THE COCKATOO
AND THE FISH.

YEAH, THE COCKATOO AND THE FISH ARE TWO DIFFERENT STORIES.

BUT, LIKE, THE REPTILE
AND THE FROG --

THE IGUANA AND THE FROG,

THEY'RE, LIKE,
NOT EXACTLY THE SAME.

BUT THEY'RE MORE ALIKE
THAN THEY ARE DIFFERENT.

Woman: DO YOU THINK THESE ANIMALS COULD BE RELATED?

NO.

I DON'T THINK SO.

SMALL POSSIBILITY.

BUT, NO, NO, THEY'RE TWO DIFFERENT SPECIES.

I MEAN, TWO DIFFERENT,
LIKE, FAMILIES.

BECAUSE THIS IS
AN AMPHIBIAN,

THIS IS A REPTILE.

THIS IS A FISH.

YEAH, THAT'S A FISH.

AND THAT'S A BIRD.

YEAH, THAT'S FISH FAMILY,
BIRD FAMILY, MAMMAL FAMILY.

THERE'S FIVE
DIFFERENT FAMILIES.

SO DO YOU THINK ALL THESE ANIMALS ARE RELATED?

UH...YEAH.

IN SOME WAY, YES.

BUT BIOLOGICALLY
OR EVOLUTIONARY, PROBABLY NO

BECAUSE I DON'T SEE HOW A RAT COULD BE RELATED TO A HORSE.

WELL, YOU NEVER KNOW.

THEY'RE TOTALLY
DIFFERENT

EXCEPT FOR THE FACT THAT
THEY BOTH HAVE FOUR LEGS.

THEY'RE BOTH MAMMALS, TOO.

BUT THEN AGAIN, IF THIS
IS RELATED TO THIS

AND THIS IS
RELATED TO THIS,

AND THIS IS SOMEWHAT
RELATED TO THAT,

THERE IS A SMALL RELATION.

IF A EQUALS B
AND B EQUAL C,

THEN A EQUALS C, SO.

BUT WHAT IF THIS
ISN'T RELATED TO THAT?

WELL...

ALL SKULLS ARE SHAPED
SORT OF LIKE THAT.

Narrator: THE IDEA THAT
VERY DIFFERENT LOOKING ANIMALS

MIGHT BE RELATED

STILL SEEMS RATHER FARFETCHED
TO MANY OF THE STUDENTS.

SO WE ASKED THEM
TO FOCUS THEIR ATTENTION

ON PARTICULAR STRUCTURES,
THE LIMBS.

IF YOU TAKE THE HUMAN
HAND AND ARM,

CAN YOU COMPARE IT
TO THE ANIMALS

AND SEE IF THERE IS ANY SIMILARITIES OR DIFFERENCES?

THEY ALL HAVE
FIVE FINGERS.

PUT THAT OVER THERE.

THIS ONE HAS FOUR,

BUT IT HAS FIVE OVER HERE.

FIVE, FIVE, FIVE, FIVE.

BUT THIS
ONE HAS THREE.

NO, THIS ONE HAS NONE.

YEAH, BECAUSE IT
DOESN'T HAVE ANY HANDS.

IT ACTUALLY HAS
ONE, TWO, THREE, FOUR.

THOSE AREN'T HANDS,
THOSE ARE LIKE --

WELL, THEY'RE
THE FLIPPER THINGIES.

WELL.

IT'S SIMILAR
WITH THE IGUANA,

BUT DIFFERENT WITH THE BIRD.

I'M JUST GOING TO USE
THE FROG AS AN EXAMPLE.

BUT THEY BOTH HAVE
THIS HOLE HERE.

IT'S MADE UP
OF TWO BONES.

THAT'S WHAT I MEANT.

AND IT'S GOT FIVE FINGERS,

ALTHOUGH THEY'RE SUPPOSED
TO BE WEBBED.

YEAH, IT'S STILL
FIVE FINGER BONES.

STILL FIVE FINGERS.

LOOKING FOR SIMILARITIES

IN THE LIMBS OF DIFFERENT VERTEBRATE GROUPS

IS A GOOD WAY
TO EXPLORE RELATEDNESS.

WHEN I LOOK AT FISH, FROG, LIZARD, AND HUMAN SKELETONS,

I CAN SEE THAT EACH HAS PARED STRUCTURES TOWARD THE HEAD

AND TAIL AREAS.

BASED ON WHAT I SEE,

FINS VERSUS LIMBS,

I WOULD SAY FROGS,
LIZARDS, AND HUMANS

ARE MORE CLOSELY
RELATED TO EACH OTHER

THAN THEY ARE TO FISH.

LOOKING AT OTHER SKELETAL FEATURES, LIKE THE SKULL,

I'D SAY FROGS AND LIZARDS

ARE MORE CLOSELY RELATED
TO EACH OTHER

THAN THEY ARE TO HUMANS.

BIRDS ARE VERTEBRATES.

WHERE DO THEY FIT IN?

THEIR FORELIMBS ARE WINGS.

THERE IS CONCLUSIVE DATA

THAT BIRDS ARE MORE CLOSELY RELATED TO REPTILES

THAN TO ANY OTHER GROUP.

AND THIS WOULD BE HARD TO INFER

BY LOOKING STRICTLY
AT THEIR SKELETONS.

HAVING SEEN THAT EVEN WE SHARE SOME FEATURES WITH ANIMALS,

AS DIFFERENT AS FISH AND BIRDS,

THE STUDENTS ARE READY TO TACKLE SOME TOUGHER QUESTIONS.

DO ALL ANIMALS
HAVE A COMMON ANCESTOR?

AND IF SO, HOW MIGHT ANIMALS HAVE EVOLVED?

A LOT OF TIMES, THERE'S

ONE ANIMAL TO START WITH --

AND THEN IT ADAPTS
IN EVERY,

IN BASICALLY EVERY
SINGLE DIRECTION.

AND THEN THEY'RE
ALL RELATED

BECAUSE THEY ALL CAME
FROM THE SAME ANIMAL

IN THE FIRST PLACE.

LIKE, UM,
LIKE WE WERE, UM,

EVOLVED FROM AN APE
OR A GORILLA.

UM, AND THEN NOW
WE'RE A HUMAN.

SO WE DID, UM,

AT ONE POINT ADAPT
INTO A DIFFERENT SPECIES

LIKE HE WAS SAYING
ABOUT THE TURTLE.

WELL, I DON'T THINK THAT ALL THESE, THEY CAME IN AN ORDER.

LIKE, FROG THE CAME FIRST
AND THEN LIZARD

THEN BIRD THEN FISH
THEN MOUSE.

I DON'T THINK
IT WAS LIKE THAT.

I THINK IT WAS
MORE LIKE --

I THINK IT COULD HAVE BEEN EVOLVED LIKE THIS.

I THINK THEY ALL
EVOLVED SEPARATELY

IN SEPARATE CHAINS.

LIKE, FIRST, SOMETHING
CAME BEFORE THE FROG

THAT WAS LIKE A FROG
BUT WASN'T EXACTLY A FROG.

IF THEY WERE EVOLVING,
I'D SAY

THEY'D SORT OF GO
LIKE THIS.

BUT THAT'S MY OPINION.

Woman: WHAT MAKES YOU SAY THAT?

WELL, FIRST WE WERE --

FROM EVERYTHING I'VE READ,

WE WERE FIRST
IN THE WATER.

WHICH WE ADAPT TO THE LAND.

THEN WE ADAPTED
MORE TO THE LAND,

LESS TO THAN THE WATER.

I HEARD THAT BIRDS,

THEY'RE A LOT LIKE
REPTILES.

SO I PUT IT IN THIS --

AND THEN THERE ARE THE EARLY BIRDS AND THE REPTILES.

THE MAMMAL, SORRY --
REPTILE.

THE CHILDREN CERTAINLY FIND

THE QUESTION OF RELATEDNESS PUZZLING.

FROM OBSERVING SIMILARITIES,

THEY SEEM WILLING TO
ACCEPT THAT WE,

ALONG WITH OTHER LIVING THINGS,

HAVE ANCESTORS THAT WERE DIFFERENT IN SOME WAY.

THE CHILDREN ARE GENERATING HYPOTHESES ABOUT ANCESTRY

BY CONSIDERING EVIDENCE
OF RELATEDNESS.

THIS IS THE WORK
OF SCIENTISTS TODAY,

TO CREATE A BODY OF EVIDENCE

THAT CAN BE USED TO CONSTRUCT
A MODEL FOR HOW LIFE EVOLVED,

A MODEL FOR THE TREE OF LIFE.

ULTIMATELY WE CAN TRACE BACK
ALL FORMS OF LIFE

ON THE PLANET EARTH TO
A SINGLE COMMON ANCESTOR.

AND CONVERSELY, GOING OUT FROM THAT COMMON ANCESTOR,

WHAT HAS HAPPENED IS A SERIES OF DIVERGING EVENTS,

AND IN SOME CASES CONVERGING.

BUT YOU'RE ULTIMATELY LEFT
WITH A TREE OF LIFE.

AND SPECIES ARE OUT AT THE TIPS.

AND SO WHAT BIOLOGICAL DIVERSITY

AT THE LEVEL OF INVENTORYING
AND NAMING SPECIES

IS BASICALLY WORKING OUT
THE IDENTITY

OF ALL OF THE DISPARATE,
THE TIPS OF THE TWIGS,

THE TWIGS AND LEAVES
ON THE TREE OF LIFE.

Narrator: THE TREE OF LIFE THAT DR. HANKEN DESCRIBES

IS A MODEL THAT SCIENTISTS
HAVE CREATED

TO DEPICT THE EVOLUTION OF LIFE
FROM ITS ANCIENT BEGINNINGS.

IT'S TREE-LIKE
BECAUSE IT HYPOTHESIZES

HOW SPECIES ARE RELATED

THROUGH COMMON ANCESTORS
AT BRANCH POINTS.

THE TREE OF LIFE HAS BEEN BUILT FROM VARIED TYPES OF EVIDENCE,

INCLUDING EVIDENCE
FROM THE FOSSIL RECORD,

COMPARISONS OF EXTERNAL
AND INTERNAL FEATURES

OF MODERN SPECIES,

AND MORE RECENTLY,
COMPARISONS OF THEIR DNA.

USING THIS EVIDENCE,
SPECIES THAT ARE VERY SIMILAR

ARE UNDERSTOOD TO BE
CLOSELY RELATED

WITH A COMMON ANCESTOR
THAT CONNECTS THEM

AT A MORE RECENT BRANCH POINT.

THE CHALLENGE IS TO FIGURE OUT WHAT THIS ANCESTOR,

A TRANSITIONAL FORM,
MIGHT HAVE BEEN LIKE.

WE PAID A VISIT TO GAIL MODUGNO'S FIFTH GRADE CLASSROOM

WHERE THE STUDENTS CONSIDERED QUESTIONS OF RELATEDNESS

TO GENERATE THEIR OWN IDEAS ABOUT COMMON ANCESTORS.

Modugno: IN THIS ACTIVITY,

I'M GOING TO TAKE
TWO PICTURE CARDS

WITH DIFFERENT SKELETONS

AND DRAW FROM THEM HOW THEY'RE SIMILAR, HOW THEY'RE DIFFERENT.

WHERE THEY MIGHT LIVE

IS GOING TO BE IMPORTANT FOR THEM TO TAKE INTO CONSIDERATION.

HOW THEY EAT.

ANYTHING SPECIAL ABOUT
THE ANIMAL, AN UNUSUAL FEATURE.

THIS ONE IS SO WEIRD

BECAUSE, LIKE, HE HAS
THIS SHOULDER BONE.

THE EYES ON THE SIDE,

MOST ANIMALS HAVE EYES
ON THE SIDE.

EAT GRASS
AND THEY'RE ALWAYS DOWN

LOOKING, EATING GRASS.

OR THEY NEED TO SEE
A PREDATOR COMING.

AND THE ANIMALS THAT HAVE
EYES ON THE FRONT

USUALLY ARE PREDATORS
THAT EAT OTHER ANIMALS.

SO THEY LOOK IN FRONT
OF THEIR EYES TO SEE

IF THERE'S
ANY ANIMALS AROUND.

Modugno: FOR A CHILD AT ANY AGE

TO REALLY UNDERSTAND
EVOLUTION,

I THINK IT ALL GOES BACK
TO TAKING A LOOK

AT THE ANIMAL ITSELF.

LOOKING AT
THE SKELETAL STRUCTURE,

LOOKING AT ITS FEATURES
AND TRYING TO FIGURE OUT

THE FORM OR THE STRUCTURE
OF THE ANIMAL AND ITS PARTS

AND THE FUNCTION OF ITS PARTS.

BECAUSE TO
UNDERSTAND EVOLUTION,

YOU NEED THOSE
AS REAL BASICS.

YOU MENTIONED
THAT YOU THOUGHT THESE

WERE MORE CLOSELY RELATED,
THESE THREE.

WHY DO YOU THINK THOSE THREE
ARE MORE CLOSELY RELATED?

BECAUSE THEY'RE
ALL MAMMALS.

THEY'RE ON LAND.

THEY...

THEY DON'T WALK
LIKE WE DO.

THEY GET ON FOUR LEGS.

THEY HAVE THE SAME
FIGURE, KIND OF.

THE SAME SKELETAL
STRUCTURE.

Modugno: WHAT WOULD IT TELL YOU ABOUT THIS WHOLE GROUP?

THAT THEY'RE PROBABLY
IN THE SAME GROUP.

THAT A LONG,
LONG TIME AGO,

THEY COULD HAVE BEEN
IN A WAY RELATED,

LIKE THERE COULD
HAVE BEEN SOMETHING

THAT CONNECTED
THEM ALL TOGETHER.

CAN YOU EXPLAIN
WHAT HAPPENED?

LIKE AN ANIMAL THAT COULD
HOP LIKE A RABBIT

AND CLIMB LIKE A MONKEY
AND RUN LIKE A CAT.

AND THAT STARTED
CHANGING AND EVOLVING

INTO THESE DIFFERENT
ANIMALS PROBABLY.

Modugno:
WHAT WAS INTERESTING TODAY WAS

AS THEY'RE COMPARING
THE ANIMALS,

THEY SAW A LOT OF RELATEDNESS.

I THINK WHAT
THEY SAW IN COMMON

WAS, JEEZ, ALL THESE ANIMALS
DO HAVE THE SAME BONE GROUPS,

THEY ALL HAVE SKULLS,
THEY ALL HAVE VERTEBRAE.

THE LEGS MIGHT BE DIFFERENT.

THE PELVIS MIGHT BE DIFFERENT,

BUT THERE'S STILL SOMETHING
IN COMMON.

AND I WAS GLAD TO SEE SOME KIDS REFER TO THE HUMAN SKELETON.

AND TO ME THAT'S A REAL STEP,

SETTING KIND OF GROUNDWORK

FOR WHAT THEY'RE GOING
TO BE LEARNING LATER ON

ABOUT THE REALLY
RELATEDNESS OF ANIMALS,

INCLUDING US.

GAIL'S STUDENTS CAME UP WITH
AN IMAGINATIVE SOLUTION

TO THE PROBLEM OF IDENTIFYING
A COMMON ANCESTOR,

A TRANSITION FORM FOR
TWO LINEAGES OF ANIMALS.

THEY'RE DOING JUST
WHAT SCIENTISTS DO,

HYPOTHESIZING BASED
ON EXISTING EVIDENCE.

TO LEARN MORE
ABOUT VERTEBRATE EVOLUTION

AND TRANSITIONAL FORMS,

PLEASE VISIT OUR WEBSITE.

Narrator: IN OUR SECOND SESSION,

"CLASSIFICATION
OF LIVING THINGS,"

WE EXPLORED A SCHEME

FOR GROUPING THE MILLIONS
OF KNOWN SPECIES ON EARTH

BASED ON SHARED FEATURES.

HOW DO THESE GROUPS
FIT INTO A TREE OF LIFE?

THINK OF THE FIRST FORM OF LIFE AS BEING THE TRUNK OF A TREE

FROM WHICH ALL SPECIES EVENTUALLY AROSE.

THIS LIFE FORM IS HYPOTHESIZED TO BE THE COMMON ANCESTOR

FOR MODERN SPECIES THAT BRANCHED VERY EARLY IN EVOLUTIONARY TIME.

INTO THE BACTERIA
AND THE ARCAHEA,

TWO OF THE THREE DOMAINS CURRENTLY USED TO CLASSIFY

ALL LIVING THINGS.

FROM THERE A BRANCH OF MORE COMPLEX ORGANISMS AROSE.

THE DOMAIN EUKARYA.

THE EARLIEST MEMBERS
OF THIS DOMAIN

ARE TO BELIEVED TO HAVE BEEN COMMON ANCESTORS

OF SPECIES CURRENTLY CLASSIFIED IN THE PROTIST KINGDOM.

RECALL THAT THE PROTISTS
ARE A CATCHALL GROUP.

FOR THIS REASON, CLASSIFICATION WITHIN THIS GROUP

MAY CHANGE IN THE FUTURE.

ANCESTRAL PROTISTS ARE THEN THOUGHT TO HAVE BRANCHED

INTO LINEAGES
THAT EVENTUALLY EVOLVED

INTO MODERN SPECIES OF PLANTS, FUNGI, AND ANIMALS.

WHERE DO THE ANIMAL EXAMPLES

WE'VE CONSIDERED TODAY FIT IN?

TWO MAJOR GROUPS BRANCHED FROM THE FIRST ANIMAL ANCESTOR,

INVERTEBRATES,
ANIMALS WITHOUT BACKBONES,

VERTEBRATES,
ANIMALS WITH BACKBONES.

SCIENTISTS HAVE CONCLUDED THAT MODERN AMPHIBIANS

EVOLVED FROM ANCESTRAL FISH.

AND MODERN REPTILES EVOLVED
FROM ANCESTRAL AMPHIBIANS.

DR. HANKEN'S SALAMANDERS
WOULD BE PLACED

AT THE TIPS OF THE BRANCHES
OF MODERN AMPHIBIANS.

HIS SNAKES AND LIZARDS
WOULD BE PLACED

AT THE TIPS OF THE BRANCHES
OF MODERN REPTILES.

RECENT EVIDENCE HAS LINKED MODERN BIRDS

TO A REPTILIAN ANCESTOR.

THIS IS WHERE DARWIN'S FINCHES WOULD BE POSITIONED.

ANOTHER GROUP
OF ANCESTRAL REPTILES

IS THOUGHT TO HAVE EVOLVED
INTO MODERN MAMMALS,

LIKE THE HORSE
AND THE HUMAN BEING.

THE TREE OF LIFE
IS SUBJECT TO CHANGE,

AS NEW EVIDENCE FOR RELATEDNESS

AND COMMON ANCESTRY EMERGES.

THE EVIDENCE OF RELATEDNESS THAT HAS HELPED SCIENTISTS

BUILD THE TREE OF LIFE
IS COMPELLING AND VARIED.

AND THE TREE OF LIFE CONTINUES
TO ADD NEW BRANCHES.

ONE IMPORTANT IMPLICATION
OF THIS MODEL

IS THAT EVOLUTION OCCURS
IN A TREE-LIKE MANNER.

THIS CONTRASTS WITH A VIEW THAT CHILDREN AND OTHERS OFTEN HAVE,

A LADDER-LIKE VIEW, WHERE ONE GROUP REPLACES ANOTHER,

EACH GROUP TYPICALLY CLIMBING
TO GREATER COMPLEXITY

AND OFTEN ENDING WITH THE HUMAN SPECIES AT THE TOP.

THERE IS NO ONE SPECIES,
OR LINEAGE,

AT THE TOP OF THE TREE OF LIFE.

AS BRANCHING OCCURRED, FORMS THAT AROSE EARLIER IN TIME

WEREN'T REPLACED.

THEIR LINEAGES
CONTINUED TO EVOLVE

INTO THE BRANCHES OF
MODERN SPECIES.

HUMANS ARE VERY RECENT
AND SIMPLY HAVE A BRANCH POINT

VERY CLOSE TO THE TOP.

DARWIN'S THEORY OF EVOLUTION
WAS AND IS

ONE OF THE MOST
INFLUENTIAL AND CONTROVERSIAL

SCIENTIFIC CONTRIBUTIONS
IN THE HISTORY OF HUMANKIND.

IT HAS FUNDAMENTALLY CHANGED

HOW PEOPLE THINK AND TALK
ABOUT LIFE ON EARTH

AND THEIR PLACE IN IT.

UNDERSTANDING THE BASICS OF EVOLUTION CAN BE EMPOWERING

IN INFORMING OUR TEACHING

AND OUR ABILITY TO HELP OUR STUDENTS MAKE SENSE OF THIS IDEA

ON THEIR OWN.

WELL, THIS IS ONE OF THOSE TOPICS THAT IS SO RICH

THAT WE COULD ONLY
SCRATCH THE SURFACE

IN OUR SESSION TODAY.

THE AMOUNT OF NEW INFORMATION THAT BECOMES AVAILABLE

ON ALMOST A DAILY BASIS
IN EVOLUTIONARY BIOLOGY

IS STAGGERING.

THE TREE OF LIFE,
WITH ITS MILLIONS OF BRANCHES,

TEACHES US THAT ALL LIFE
IS BOUND TOGETHER

BY A SHARED
AND CONTINUING STORY.

IT GIVES ME PERSPECTIVE
TO KNOW THAT 99.99%

OF ALL SPECIES THAT HAVE EVER LIVED ON THE PLANET

ARE NOW EXTINCT.

THIS IS THE CONTINUING OUTCOME
OF NATURAL SELECTION.

IN THE FINAL TWO SESSIONS,

WE'RE GOING TO EXAMINE
ONE OUTCOME OF EVOLUTION,

THE INTERDEPENDENCE OF SPECIES.

THANKS FOR BEING WITH US.

SEE YOU NEXT TIME.

GOODBYE.
GOODBYE.

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