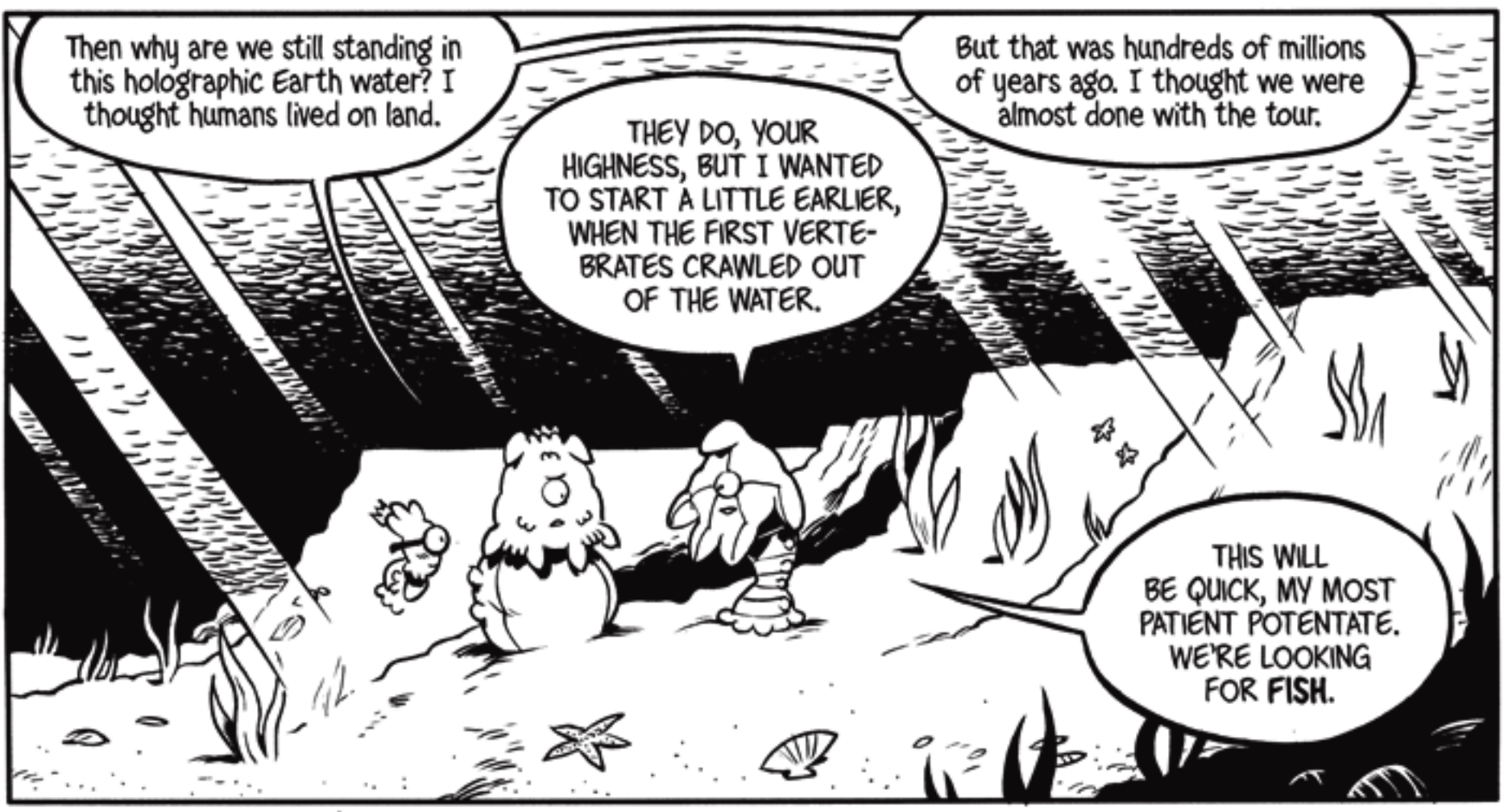
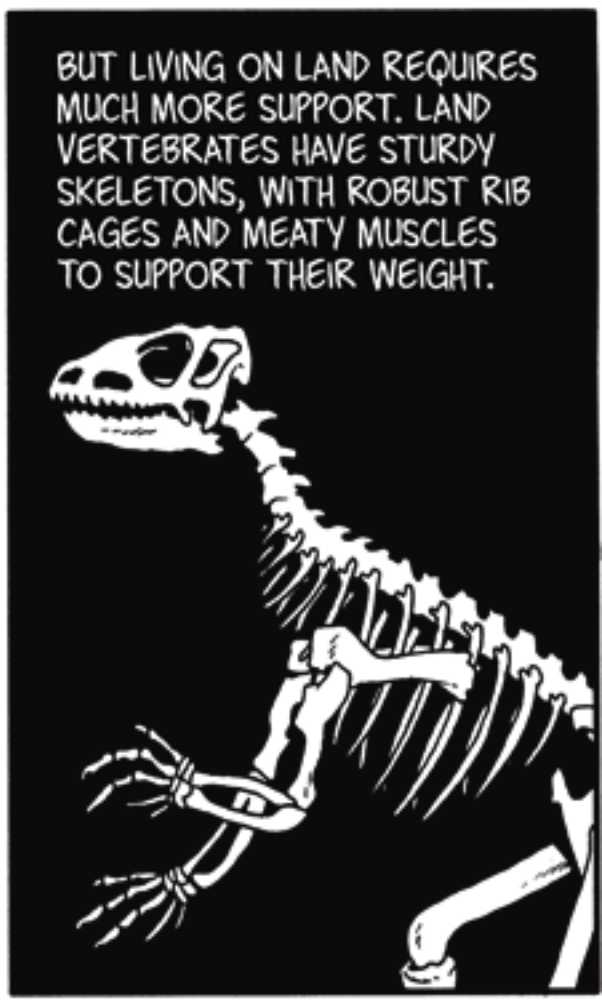
CHAPTER 6

Getting a Leg Up on Evolution





Oh, come now, Bloort, can a skeleton really be **THAT** important?

WELL, YOUR HIGHNESS, AS PART OF THE TOUR I HAVE CONSTRUCTED A TERRESTRIAL SIMULATOR TO GIVE VISITORS A SENSE OF THE DIFFERENCE BETWEEN LIVING IN WATER AND LIVING ON LAND.

Ooo, goody.

I claim royal privilege and will go first.

I HAVE FIELD GENERATORS FOR BOTH OF YOU. WE JUST NEED TO SLIP THEM AROUND YOUR WAISTS.

I'm still going first.

Okay, but I get to work the controls.

I'M NOT SO SURE THAT'S...

Ready, Dad?

Ready, Son!

BEEP.

SQU

Turn it off, turn it off now.

Not yet, this is hilarious.

HAHAHA

Uh-oh.

CLICK.

OH DEAR, OH DEAR, OH DEAR...

BOING

Hee heee, let's do that again!

HEH -- GULP -- A-AS YOU CAN SEE, BECAUSE WE SQUINCHES LIVE IN WATER, WE COULD THRIVE WITHOUT A BULKY INTERNAL SKELETON.

So...

...we're not well suited for living on land. Why did Earth creatures leave the ocean?

WELL, SIRE, THE LAND HAD NEW, UNEXPLOITED NICHES, AND AIR CONTAINS FORTY TIMES MORE OXYGEN THAN WATER.

So, exploration would be rewarded with access to new markets and vast oxygen wealth?

IN A MANNER OF SPEAKING, O IMPERIALISTICALLY MINDED ONE. ORGANISMS WITH ADAPTATIONS TO INVADE THE LAND WOULD HAVE SOME EXCITING EVOLUTIONARY POSSIBILITIES.

But how did they make that leap, Bloort? These fish don't seem very well suited for life in such a hostile environment.

MOST AREN'T, YOUR HIGHNESS.

THE VAST MAJORITY OF FISH ARE **RAY-FINNED** FISH AND THEIR FINS ARE LITTLE MORE THAN A FLAP OF SKIN SUPPORTED BY SOME THIN BONY SPIKES.

GASP -- I'M... ...LIKE A... GASP... FISH OUT OF WATER.

BUT DURING THE SILURIAN PERIOD -- ALMOST 450 MILLION YEARS AGO -- A SMALL GROUP CALLED THE **LOBE-FINNED** FISH PLAYED A HUGE ROLE IN THE MOVE TO LAND.

LOBE-FINNED FISH ARE CHARACTERIZED BY FLESHY FINS THAT ARE FULL OF BONES.

NICE FINS, WEIRDO.

TODAY ONLY A FEW SPECIES SURVIVE. **COELACANTHS** LIVE IN THE WATERS OFF THE EASTERN COAST OF SOUTHERN AFRICA AND HAVE CHANGED VERY LITTLE FOR HUNDREDS OF MILLIONS OF YEARS...

EVERY MILLENNIUM IT'S THE SAME OLD THING: FLOAT, EAT, SLEEP. FLOAT, EAT, SLEEP...

...WHILE THE LUNGFISH OF AFRICA, SOUTH AMERICA, AND AUSTRALIA RETAIN MANY ANCIENT CHARACTERISTICS, SUCH AS AN ELABORATE SKELETON, BEEFY FINS TO CRAWL ACROSS LAND WHEN THEIR WATER DRIES UP, AND PRIMITIVE LUNGS TO BREATHE WATER.

THIS POND AIN'T BIG ENOUGH FOR THE BOTH OF US.

I'M A-GOIN', I'M A-GOIN'.

THE LOBE-FINNED FISH WERE NEVER AS SUCCESSFUL IN WATER AS THEIR RAY-FINNED COUSINS. THEIR EVOLUTIONARY LEGACY WOULD BE ON LAND.

Something like **THESE** fish would make the **LEAP** to land?

MORE LIKE THE **CRAWL** TO LAND, YOUR MAJESTY.

THERE WAS A THIRD, NOW EXTINCT, GROUP OF LOBE-FINNED FISH CALLED THE **TETRAPODOMORPHS** THAT WOULD BECOME THE ANCESTORS TO ALL TERRESTRIAL VERTEBRATES.

Tetra-whatta-**WHAT?**

TETRAPODOMORPH. IT MEANS "FOUR FOOT SHAPE."

THEIR TRANSITION FROM FISH TO LAND VERTEBRATE IS DETAILED EXQUISITELY IN THE FOSSIL RECORD.

BUT ONE RECENT FOSSIL DISCOVERY HAS BEEN PARTICULARLY EXCITING.

IN 2006, THE EARTH SCIENTIST NEIL SHUBIN DISCOVERED AN IMPORTANT FOSSIL CALLED **TIKTAALIK**.

Tik-TAH-lik?

Where do they come up with these names?

TIKTAALIK WAS A LOBE-FINNED FISH THAT HAD SOME KEY FEATURES THAT DISTINGUISHED IT FROM THE FISH THAT HAD PRECEDED IT. UNLIKE ANY FISH, IT HAD A **NECK**, SO IT COULD LOOK AROUND.

LOOK BOTH WAYS BEFORE CROSSING THE SHORELINE, DEAR.

AND IT HAD SPECTACULAR LEGS.

THANK YOU! I DO A HUNDRED PUSH-UPS EVERY DAY.

They really don't look that impressive to me.

HMPH!

AH, TO FULLY APPRECIATE TIKTAALIK'S LIMBS, WE MUST FIRST TAKE A LOOK AT THE LIMBS OF VARIOUS VERTEBRATES.

ALL VERTEBRATES' LIMBS SHOW THE SAME BASIC PATTERN: STARTING AT THE SHOULDER, WE SEE -- AS PROFESSOR SHUBIN POINTS OUT -- ONE BONE, TWO BONES, A BLOB OF LITTLE BONES, AND THEN FIVE DIGITS.

THIS IS TRUE FOR HUMANS...

HUMERUS

ULNA

RADIUS

HUMAN

...FROGS...

ONE BONE, TWO BONES, A BLOB OF LITTLE BONES, AND THEN FIVE DIGITS.

...LIZARDS...

ONE BONE, TWO BONES, A BLOB OF LITTLE BONES, AND THEN FIVE DIGITS.

Interesting, but...

WE SEE IT REPEATED AGAIN AND AGAIN AND AGAIN!

CAT

CAT: SNEAKING AND POUNCING

GAZELLES: RUNNING AND LEAPING

ELEPHANT: STOMPING

DOLPHIN: SWIMMING

BAT: FLYING

MOLE: DIGGING

HUMAN

These limbs have very different functions, but they are constructed using the same basic plan.

THAT'S RIGHT.

THE SIMILARITIES YOU SEE IN THE LIMBS OF VERTEBRATES ARE CALLED HOMOLOGIES.

A **HOMOLOGOUS** TRAIT IS A TRAIT THAT TWO OR MORE SPECIES INHERITED FROM A COMMON ANCESTOR. HOMOLOGIES CAN BE ANATOMICAL, GENETIC, OR DEVELOPMENTAL.

ONE OF THE REASONS TIKTAALIK IS IMPORTANT...

...IS THAT SHE SET THE BASIC BODY PLAN FOR ALL OF THEM.

SNAP!

RADIUS

ULNA

HUMERUS

So you're saying that all vertebrates have the same pattern of bones in their limbs because they all descended from a common ancestor who had that pattern?

I HAVE TO "HAND" IT TO YOU, YOUR HIGHNESS, YOU ARE REALLY GETTING A "LEG UP" ON THIS MATERIAL.

That was **AWFUL**, Bloort.

giggle

Hmm, I prefer it when he grovels.

AS YOU WISH, SIRE. YOUR PATIENCE WITH MY FEEBLE WITTICISMS IS EXCEEDED ONLY BY THE VASTNESS OF YOUR INFINITE INTELLECTUAL ACUMEN.

That's more like it.

TIKTAALIK HAD AN ADAPTATION THAT DRAMATICALLY INCREASED HER EVOLUTIONARY SUCCESS, AND SHE PASSED IT ALONG TO ALL OF HER DESCENDANTS.

THE VERTEBRATE LIMB HAS BEEN AN ENORMOUSLY IMPORTANT AND VERSATILE ADAPTATION. IT HAS EVOLVED INTO A DAZZLING ARRAY OF VARIATIONS, BUT EACH IS STILL JUST A VARIATION ON THE SAME THEME.

THE HIGH DEGREE OF HOMOLOGY BETWEEN THE BONES OF VERTEBRATES AND HUMANS SPARKED MANY EARTH SCIENTISTS TO SPECULATE ON HOW THEY THEMSELVES WERE RELATED TO OTHER ANIMALS.

TONIGH
ARE
HUMAN
RELATED TO
APES
T. H. Huxley

DARWIN'S CONTEMPORARY **T. H. HUXLEY** BECAME FAMOUS FOR GIVING PUBLIC LECTURES ABOUT THE SIMILARITIES BETWEEN HUMAN SKELETONS AND THE SKELETONS OF THEIR NEAREST PRIMATE RELATIVES.

IT IS QUITE CERTAIN THAT THE APE WHICH MOST NEARLY APPROACHES MAN IS EITHER THE CHIMPANZEE OR THE GORILLA...

GORILLA

MAN

Whoa, whoa, whoa, Bloort. You're getting ahead of us with the terminology. Primate? Chimpanzee? Gorilla?

APOLOGIES, YOUR HIGHNESS. PERHAPS IT WOULD BE BEST TO TAKE A STEP BACK AND CONSIDER WHERE HUMANS SIT IN RELATION TO OTHER ANIMALS.

FIRST, WE KNOW THAT HUMANS ARE **MULTICELLED EUKARYOTES.** ALL EUKARYOTES SHARE SOME FUNDAMENTAL FEATURES: THEY HAVE CELLS WITH NUCLEI AND LINEAR DNA.

EUKARYOTES

HUMANS ARE **ANIMALS**, WHICH MEANS THEY MOVE AROUND AND EAT OTHER THINGS. THEY CANNOT MAKE THEIR OWN FOOD LIKE PLANTS CAN.

ANIMALS

WITHIN THE ANIMALS, HUMANS ARE IN A GROUP CALLED **MAMMALS**.

MAMMALS

The furry little creatures with mammary glands and biggish brains?

EXCELLENT MEMORY, SIRE. MAMMALS CAN BE FURTHER SORTED INTO EVEN SMALLER, SPECIALIZED CATEGORIES BASED UPON THEIR HOMOLOGOUS TRAITS.

HUMANS ARE PART OF A SUBSET OF MAMMALS CALLED **PRIMATES**. THE PRIMATES ARE PRIMARILY TREE-DWELLING MAMMALS THAT INCLUDE MONKEYS, LEMURS, TARSIERS, AND APES.

PRIMATES

WITHIN THE PRIMATES, HUMANS ARE PART OF AN EVEN SMALLER GROUP OF LARGE, TAILLESS PRIMATES CALLED **APES**.

APES

Hmph. They all look the same to me.

AH, BUT I'M SURE THAT YOUR KEEN ROYAL EYES CAN FIND DIFFERENCES IF YOU LOOK HARD ENOUGH, SIRE.

Their arms are different lengths...

I guess some are bigger than others.

Some are hairier than others.

And their heads seem to be of different sizes and shapes.

TRULY, ALL OF GLARGAL IS LUCKY INDEED TO HAVE SUCH SHARP EYES WATCHING OVER US!

HUXLEY USED THE SHARED ANATOMICAL FEATURES TO BUILD AN EVOLUTIONARY FAMILY TREE FOR ALL OF THE APES.

How do I read this, Bloort?

CHIMPANZEE

BONOBO

GORILLA

HUMAN

ORANGUTAN

GIBBON

APES

10

11

12

13

14

15

16

17

18

19

(MILLIONS of YEARS AGO)

WELL, YOUR HIGHNESS, EACH BRANCH POINT IS A PLACE IN WHICH THE EVOLUTIONARY TRAJECTORY OF TWO SPECIES DIVERGED.

So at this point, about 6 million years ago, human ancestors split from chimpanzee ancestors.

WELL SAID, YOUR HIGHNESS. THAT POINT MARKS THE LAST COMMON ANCESTOR THAT CHIMPS AND HUMANS SHARED.

ALTHOUGH HUXLEY BUILT THIS TREE BASED ON NOTHING MORE THAN ANATOMICAL DATA, HIS RESULTS HAVE LONG SINCE BEEN CONFIRMED BY COMPARING THE GENETIC MAKEUP OF THE GREAT APES.

CHIMPS AND HUMANS SHARE 98% HOMOLOGY OF THEIR DNA, WHILE HUMANS AND GORILLAS SHARE 97% HOMOLOGY.

That's not much difference.

OH, BUT YOUR HIGHNESS, HAVE WE NOT SEEN DRAMATIC ANATOMICAL DIFFERENCE ARISE FROM SMALL GENETIC CHANGES?

Remember those male isopods that had three phenotypes due to variation in **ONE** gene, Dad?

Ah, yes, and Belyaev's doggy-foxes were the product of selection on a **SINGLE** gene.

BONOBO

HUMAN

CHIMPANZEE

6 MILLION YEARS AGO

COMMON ANCESTOR

THE 98% GENETIC HOMOLOGY TELLS US THAT SPECIES ARE CLOSELY RELATED. BUT A 2% DIFFERENCE CAN LEAD TO SOME **SIGNIFICANT** VARIATION.

WITHIN THAT VARIATION ARE THE ADAPTATIONS THAT ALLOWED HUMANS TO BECOME... WELL...

...**HUMAN.**

AS WE'VE SAID, THE HUMAN EVOLUTIONARY LINE AND THE CHIMP EVOLUTIONARY LINE SPLIT ABOUT 6 MILLION YEARS AGO. BUT HUMANS WEREN'T HUMANS 6 MILLION YEARS AGO. THESE ANCESTORS TO MODERN HUMANS WERE CALLED **HOMINIDS.**

OOO OOOK!*

OO EE OO!**

* FARE THEE WELL.

** ALAS, PARTING IS SUCH SWEET SORROW.

ABOUT 1.6 MILLION YEARS AFTER THE HOMINDS SPLIT FROM THE CHIMPS, THEY DID SOMETHING **REVOLUTIONARY.**

Wait, wait, don't tell me. They invented jet packs.

UH, NO, SIRE, THEY...

Think, Son. They didn't have the technology to make rocket fuel.

Bloort probably means they built some kind of wheeled device that they propelled with feet.

WHAT? NO... UM --

ACTUALLY, THE REVOLUTIONARY THING THEY DID WAS... **STAND UP.**

And then strap on a jet pack?

NO, JUST STAND UP.

Bloort, we need to discuss your definition of "revolutionary."

BUT IT **WAS**, YOUR HIGHNESS. IN SO MANY UNIMAGINABLE WAYS!

VERY RECENTLY, EARTH SCIENTIST TIM WHITE AND A TEAM OF EXPERTS DISCOVERED ONE OF THE OLDEST HOMINID FOSSILS EVER FOUND.

ARDIPITHECUS RAMIDUS -- NICKNAMED **ARDI** -- LIVED 4.4 MILLION YEARS AGO.

So that would have been about 1.6 million years **AFTER** the hominid and chimp lines split.

CORRECT, O NUMERICALLY NIMBLE ONE. AND IN THAT TIME, ARDI EVOLVED SOME INTERESTING TRANSITIONAL FEATURES.

FIRST, HER FOOT BECAME STIFFER THAN A CHIMP'S. A RIGID FOOT ACTS AS A LEVER THAT MAKES WALKING ON TWO FEET EASIER. MODERN HUMANS ALSO HAVE A RIGID FOOT.

MY FOOT'S KIND OF STIFF.

EXCELLENT. LET'S GO FOR A WALK.

BUT IN SOME WAYS, ARDI'S FOOT IS A SNAPSHOT OF A FOOT IN EVOLUTIONARY TRANSITION BECAUSE IT RETAINED AN **OPPOSABLE BIG TOE.** THIS PROBABLY MADE IT EASIER FOR HER SPECIES TO CLIMB THE TREES OF HER FOREST HOME.

I MEANT A WALK ON THE **GROUND.**

WALKING ON TWO LEGS SET IN MOTION A SERIES OF EVOLUTIONARY DOMINOES FOR THE HOMINIDS.

KICK!

MODIFIED TOES

MODIFIED LEGS

MODIFIED PELVIS

MODIFIED BACKBONE

MODIFIED SKULL

LESS THAN A MILLION YEARS AFTER ARDI, ANOTHER HOMINID CALLED *AUSTRALOPITHECUS AFARENSIS*-- NICKNAMED **LUCY** -- WOULD EVOLVE A FOOT VIRTUALLY INDISTINGUISHABLE FROM MODERN HUMANS'.

THESE FEET ARE MADE FOR **WALKIN'**.

HOW ARE THEY FOR **RUNNING**?

CHIMPANZEE

ARDI

LUCY

LUCY'S BIG TOE HAD EVOLVED TO SIT BESIDE THE OTHER FOUR TOES, WHICH WERE MUCH SMALLER THAN THE SAME FOUR TOES ON A CHIMP OR GORILLA FOOT.

LUCY'S SPECIES ALSO EVOLVED AN ARCH AND A LONG HEEL TO ABSORB THE SHOCK OF WALKING. THESE TWO CHANGES ALLOWED THEM TO WALK FOR VERY LONG TIMES COMPARED TO OTHER APES.

ARE WE THERE YET?

SIGH

WALKING UPRIGHT FOR LONG PERIODS OF TIME MEANT OUR **PELVISES** NEEDED TO BECOME MORE **BOWL-SHAPED** TO SUPPORT OUR GUTS.

SHH. WE HAVEN'T EVOLVED LANGUAGE YET.

THEIR SPINES BECAME S-SHAPED FOR BETTER SHOCK ABSORPTION.

WHAT'S AN "S"?

YOU'RE STILL TALKING.

OOOK. OOK. IS THAT BETTER?

SHUT UP!

THEIR LEGS BECAME LONGER AND STRAIGHTER THAN THE LIMBS OF THEIR BOW-LEGGED APE COUSINS.

AND THEIR SKULLS NOW SAT ON TOP OF THEIR SPINES.

IT'S VERY NICE UP THERE. LOTS OF ROOM TO GROW. CAN LANGUAGE BE FAR BEHIND?

NO, BUT UNTIL THEN, NO TALKING!

THE RESULT WAS AN ORGANISM VERY WELL SUITED FOR LIVING LIFE ON TWO LEGS.

But wasn't all that walking **EX-HAUSTING**?

ACTUALLY, YOUR HIGHNESS, SCIENTISTS HAVE COMPARED THE ENERGY REQUIRED TO WALK ON TWO LEGS WITH THE ENERGY REQUIRED TO WALK ON ALL FOURS LIKE A CHIMP. WALKING ON TWO LEGS USES **75% LESS ENERGY**!

My word, such an energy savings would be a tremendous advantage!

INDEED, YOUR HIGHNESS. BUT IT ALSO DID SOMETHING MORE SIGNIFICANT. IT FREED THEIR **HANDS** TO EXPLORE THEIR WORLD.

HOMINIDS USED THEIR HANDS TO POKE AND PROD THE WORLD LIKE NO OTHER CREATURE BEFORE THEM. THEIR HANDS EVOLVED AGILE OPPOSABLE THUMBS THAT ALLOWED THEM TO GRASP, CARRY, AND SHAPE OBJECTS.

KNOCK IT OFF, OR I'M TELLIN' MOM.

POKE POKE POKE POKE

But...this chimp's thumb looks opposable, too, Bloort.

PICK!

IT IS, SIRE. BUT THE CHIMP'S THUMB COULD TOUCH ONLY ITS FIRST TWO FINGERS. THE HOMINID THUMB COULD TOUCH WHAT HUMANS CALL THEIR RING FINGER AND THE PINKY.

:WINK:

ALONG WITH THE THUMB CAME ADAPTATIONS IN THE TENDONS OF THE HAND THAT ALLOWED THE WRIST TO SWIVEL AND MOVE FAR MORE THAN IN APES.

oooOoo AAH!

!!

!!

THIS ADDED DEXTERITY WOULD BE A TREMENDOUS ADVANTAGE BECAUSE IT GAVE SOME HOMINID SPECIES THE ABILITY TO MAKE **TOOLS**.

Surely **OTHER** creatures on Earth use tools, Bloort.

OH, INDEED THEY **DO**, YOUR HIGHNESS. MANY SPECIES USE THEM. CHIMPS USE LEAVES OR GRASS TO PULL TERMITES FROM THEIR MOUNDS...

FINALLY. IT IS SO NICE TO GET OUT OF THAT STUFFY COLONY FOR A WHILE.

...EGYPTIAN VULTURES USE ROCKS TO CRACK OPEN OSTRICH EGGS...

HOW WOULD YOU LIKE YOUR EGGS, DEAR?

CRACKED OPEN AND RUNNY, PLEASE.

...AND WHEN DOLPHINS FORAGE ON THE SEA FLOOR, SOME HOLD SPONGES IN THEIR MOUTHS TO PROTECT THEIR NOSES FROM GETTING ALL SCRATCHED UP.

IT MAY LOOK WEIRD, BUT IT'S FOR A GOOD PORPOISE.

BUT, IN THESE AND OTHER CASES, THE ANIMALS ARE USING OBJECTS THEY'VE **FOUND** TO PERFORM A TASK.

ONLY THE HOMINIDS EVOLVED SPECIES LIKE *HOMO HABILIS*, WHICH MEANS "HANDY MAN," THAT COULD TRANSFORM AN OBJECT LIKE A **STONE**...

...INTO A **KNIFE**.

AND THEN ADD A STICK TO MAKE IT A **SPEAR**.

HOMO HABILIS

THESE TOOLS WOULD BECOME ESSENTIAL TO THEIR SUCCESS IN GETTING MEAT TO EAT. AT FIRST, THEY PROBABLY JUST ATE WHAT THEY COULD SCAVENGE...

SIGH --

LEFTOVERS AGAIN?

...BUT EVENTUALLY THEY STARTED USING TOOLS TO HUNT THEIR FOOD WITH.

THIS FAST FOOD IS KILLING ME.

THE HIGH PROTEIN AND FAT CONTENT OF MEAT MAY HAVE FUELED SIGNIFICANT GROWTH IN THE SIZE OF SOME HOMINID BRAINS. AND WHEN THEY INVENTED COOKING THEY COULD EAT EVEN MORE BECAUSE THE MEAT BECAME EASIER TO DIGEST!

Y'KNOW WHAT WE NEED TO DO? WE NEED TO INVENT S'MORES.

AS THESE WELL-FED HOMINIDS USED THEIR NIMBLE THUMBS AND HANDS TO MAKE TOOLS, THEIR GROWING MINDS WERE ALSO BEING RESHAPED.

EARTH SCIENTISTS ARE NOW DISCOVERING THAT THE PART OF THE BRAIN THAT CONTROLS LANGUAGE DEVELOPED FROM THE PART OF THE BRAIN THAT CONTROLS HUMAN HANDS.

If I understand what you're saying, Bloort, limbs have had a huge effect on human evolution.

Adaptations in hominid feet and legs allowed them to stand up.

TA-DAAA!

This freed their hands from walking and led to the evolution of highly opposable thumbs and terrific dexterity.

SOME PUT THAT DEXTERITY TO BETTER USE THAN OTHERS.

WHAT?

This made it possible for some hominids to make tools, which in turn helped reshape their brains and made language possible.

WELL SAID, AS ALWAYS, YOUR HIGHNESS. EVENTUALLY, ADAPTATIONS IN THE HUMAN **PHARYNX** ALLOWED THEM TO MAKE SOPHISTICATED VOCALIZATIONS TO COMMUNICATE THEIR IDEAS.

Don't the other apes have a pharynx, Bloort?

THEY DO, SIRE. BUT THE HUMAN PHARYNX IS POSITIONED LOWER IN THE THROAT AND, UNLIKE IN THEIR CHIMP COUSINS, THE HUMAN PHARYNX AND BREATHING TUBE IS RIGHT BESIDE THE TUBE HUMANS USE TO EAT. CONSEQUENTLY, HUMANS CANNOT BREATHE AND SWALLOW AT THE SAME TIME.

★ = PHARYNX

BEFORE THE INVENTION OF A PROCEDURE CALLED THE **HEIMLICH MANEUVER**, CHOKING WAS THE 6th LEADING CAUSE OF DEATH IN HUMANS.

HURCK!!

ARE YOU OKAY?

? ?

I'M FINE.

NOW, WHAT WAS I SAYING?

It is a trade-off! They get to speak, but it comes with a price.

I STAND IN AWE OF YOUR INEXHAUSTIBLE INTELLECT, YOUNG SIRE. TRULY YOU HAVE AN ASTONISHING ABILITY TO DRAW TOGETHER THE MANY THREADS OF THIS TOUR.

So they now can walk, talk, create, and share ideas. What an amazing end to their evolutionary journey.

BUT THAT ISN'T THE **END**, SIRE.

Yes, **YES**, of course, they got more sophisticated with their toolmaking and eventually visited their **MOON**.

What I mean is, now that they're intelligent, self-aware beings, they've stopped evolving.

BUT THAT'S JUST IT. THEY **HAVEN'T** STOPPED EVOLVING, SIRE. THE ONLY SPECIES THAT STOP EVOLVING ARE, WELL...

...extinct!

AND HUMANS ARE FAR FROM THAT.

WITH THE ADVENT OF AGRICULTURE 10,000 YEARS AGO, HUMANS BEGAN TO ADAPT TO NEW FOODS.

FOR EXAMPLE, MOST MAMMALS CONSUME MILK ONLY AS INFANTS. AS THEY GROW OLDER, THEY CAN NO LONGER DIGEST A MILK SUGAR CALLED **LACTOSE**.

ICK!

I DON'T KNOW HOW THEY DRINK THAT STUFF.

BUT HUMAN POPULATIONS THAT DEPEND ON LIVESTOCK FOR THEIR SURVIVAL HAVE EVOLVED GENES THAT ALLOW THEM TO DIGEST LACTOSE AS ADULTS.

GOOD THING, TOO. MY LATTE WOULDN'T BE MUCH WITHOUT MY FOAMED MILK.

I LIKE VANILLA.

So, it was an advantage to be able to digest that sugar?

ABSOLUTELY, YOUR HIGHNESS. ALL EARTH ORGANISMS RELY ON SUGARS TO FUEL THEIR BODIES.

CROP TILL YOU DROP

AFTER THE INVENTION OF AGRICULTURE, AROUND 10,000 YEARS AGO, HUMAN POPULATIONS ACTUALLY GOT AN AVERAGE OF FIVE INCHES SHORTER! HOW CAN AN ABUNDANCE OF FOOD CAUSE SUCH A CHANGE?

EARLY HUMANS WERE ADAPTED TO LIFE AS HUNTER-GATHERERS AND THEY ATE A LOT OF MEAT RICH IN VITAMINS AND NUTRIENTS. WHEN HUMANS SHIFTED TO AN AGRICULTURAL LIFE, THEIR MEAT CONSUMPTION DRASTICALLY DECREASED AND THEY FOUND THEMSELVES IN AN ENVIRONMENT TO WHICH THEY WERE NOT WELL SUITED.

FARMING CREATED A LOT OF FOOD, BUT THAT FOOD HAD FEWER NUTRIENTS THAN A MOSTLY MEATY DIET. AS A RESULT, THE NEW DIET DROVE THE EVOLUTION OF SMALLER CRANIUMS, SHORTER BODIES, AND LIGHTER BONES. IN NORTHERN LATITUDES, IT MAY ALSO HAVE CONTRIBUTED TO A DIVERSITY OF SKIN COLORS.

ONE OF THE NUTRIENTS FOUND IN MEAT THAT'S MISSING IN THESE NEW CROPS WAS VITAMIN D, WHICH IS NEEDED FOR KEEPING BONES STRONG AND HEALTHY. BUT MEAT IS NOT THE ONLY SOURCE OF VITAMIN D. IT CAN ALSO BE MADE IN A PERSON'S SKIN BY ABSORBING ULTRAVIOLET RAYS FROM THE SUN. LIGHTER SKIN MAKES IT POSSIBLE TO ABSORB MORE SUNLIGHT. PEOPLE LIVING IN THE NORTH GET LESS SUN DURING THE YEAR THAN PEOPLE LIVING IN THE SOUTH, SO NATURAL SELECTION FAVORED LIGHTER SKIN AMONG THE NORTHERN FARMERS.

HUMAN POPULATIONS ALSO EVOLVED NEW GENES TO MAKE THE ENZYMES NEEDED TO DIGEST THE ABUNDANT CARBOHYDRATES IN THE GRAINS THEY WERE GROWING. WHEN CARBOHYDRATES ARE BROKEN DOWN, THEY PRODUCE SUGARS. NEW GENES EVOLVED FOR REGULATING THE HORMONE INSULIN, WHICH STIMULATES CELLS IN THE BODY TO ABSORB THOSE SUGARS.

SOME RESEARCHERS BELIEVE THAT AGRICULTURE ACCELERATED HUMAN EVOLUTION BY ONE HUNDRED TIMES IN THE LAST 10,000 YEARS. IF THEY ARE RIGHT, THEN WE TRULY ARE WHAT WE EAT.

WHEN COMPARING HUMANS TO THEIR CLOSEST RELATIVES, THE CHIMPS, WE CAN SEE OTHER RECENT DRAMATIC CHANGES. CONSIDER THE PROTEIN ENZYME **AMYLASE**, WHICH BREAKS DOWN STARCH INTO GLUCOSE, THE PRIMARY SUGAR THE BODY CAN USE.

CHOMP!

STARCH

AMYLASE

GLUCOSE

GLUCOSE

GLUCOSE

CHIMPS HAVE ONE GENE TO MAKE AMYLASE, BUT HUMANS CAN HAVE UP TO TEN COPIES. THESE EXTREME CASES ARE SEEN IN POPULATIONS THAT RELY HEAVILY ON STARCHY FOODS -- SUCH AS RICE -- FOR THEIR SURVIVAL.

AMYLASE

AMYLASE

AMYLASE

AMYLASE

AMYLASE

AMYLASE

AMYLASE

All this talk of food is making me hungry, Bloort. Are there any nondietary examples?

THERE ARE A NUMBER OF EXAMPLES, YOUR HIGHNESS.

AS THE HUMANS MOVED OUT OF AFRICA INTO EUROPE, IT BECAME ADAPTIVE TO LOSE MUCH OF THEIR PIGMENTATION.

Yikes. They look kind of pasty. Is that healthy?

ACTUALLY, SIRE, IT WAS AN IMPORTANT ADAPTATION. HUMAN SKIN ABSORBS ULTRAVIOLET RADIATION FROM SUNLIGHT AND USES IT TO MAKE **VITAMIN D**, A MOLECULE CRUCIAL TO THEIR GOOD HEALTH.

AS HUMANS MOVED NORTH INTO EUROPE, THEY EXPERIENCED LESS DIRECT SUNLIGHT. THIS DROVE THE LOSS OF PIGMENTATION IN THESE POPULATIONS BECAUSE PALE SKIN CAN ABSORB MORE LIGHT TO MAKE SUFFICIENT LEVELS OF VITAMIN D.

MORE PIGMENTATION = LESS SUNLIGHT ABSORPTION

LESS PIGMENTATION = MORE SUNLIGHT ABSORPTION

HUMAN POPULATIONS IN TIBET LIVE HIGH IN THE HIMALAYA MOUNTAINS, WHERE OXYGEN IS THINNER THAN IT IS AT LOWER ALTITUDES.

IN RESPONSE TO THIS ENVIRONMENTAL CHALLENGE, A MUTATED FORM OF THE MOLECULE HEMOGLOBIN HAS EVOLVED IN TIBETAN POPULATIONS. TIBETAN HEMOGLOBIN BINDS OXYGEN MORE TIGHTLY THAN THE HEMOGLOBIN FOUND AT LOWER ALTITUDES.

O_2

HEMOGLOBIN

IT'S MINE, ALL MINE!!

Hemoglobin? That oxygen-grabbing molecule that the icefish have lost?

THE SAME, YOUR HIGHNESS.

My goodness, these Earth creatures really **ARE** all related, aren't they?

And **STILL EVOLVING.**

YES, YOUR HIGHNESS.

BY SOME ESTIMATES, HUMAN EVOLUTION IS PROCEEDING 100 TIMES FASTER THAN IT DID BEFORE THE ADVENT OF AGRICULTURE.

BIP

BOOP

Astonishing.

There is so much to take in, Bloort.

I agree, but the adaptability of life on Earth... the dramatic power of small genetic changes...the humans' ability to manipulate the evolution of another species...it gives me hope that we can find a solution to our genetic crisis, Bloort.

Absolutely. If humans can manipulate the evolutionary trajectory of other species, surely we squinches can do the same for ourselves.

And it wouldn't necessarily require a huge genetic change, perhaps just the right gene or two.

We could explore the diversity of squinches and see if the answer isn't somewhere in our populace.

And if it isn't, perhaps we can **ENGINEER** the changes we need to avoid extinction.

SMACK!

This holographic museum is a true service to the squinches of Glargal. You should give Bloort a big grant, Dad.

YOUR PRAISE OVERWHELMS MY HUMBLE, GRASPING MIND, O MOST MAGNANIMOUS ONE.

Right, well, we better get going, then. Lots to think about, lots to think about...

RIGHT THIS WAY, SIRE. WE HAVE BUT ONE STOP LEFT ON OUR TOUR.

Another one? Seriously, Bloort, I'm getting hungry.

SMALL SNACK CAKES ARE PROVIDED, MOST ROBUST ONE.

Well, in **THAT** case, lead on.