NATGEO.ORG/EXPLORERMAG | VOL. 20 NO. 1

NATIONAL GEOGRAPHIC

TEACHERS' CHOICE AWARD TCA FOR THE CLASSROOM 2019 LEARNING MAGAZINE

Explorer

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Wildlife and Wild Places

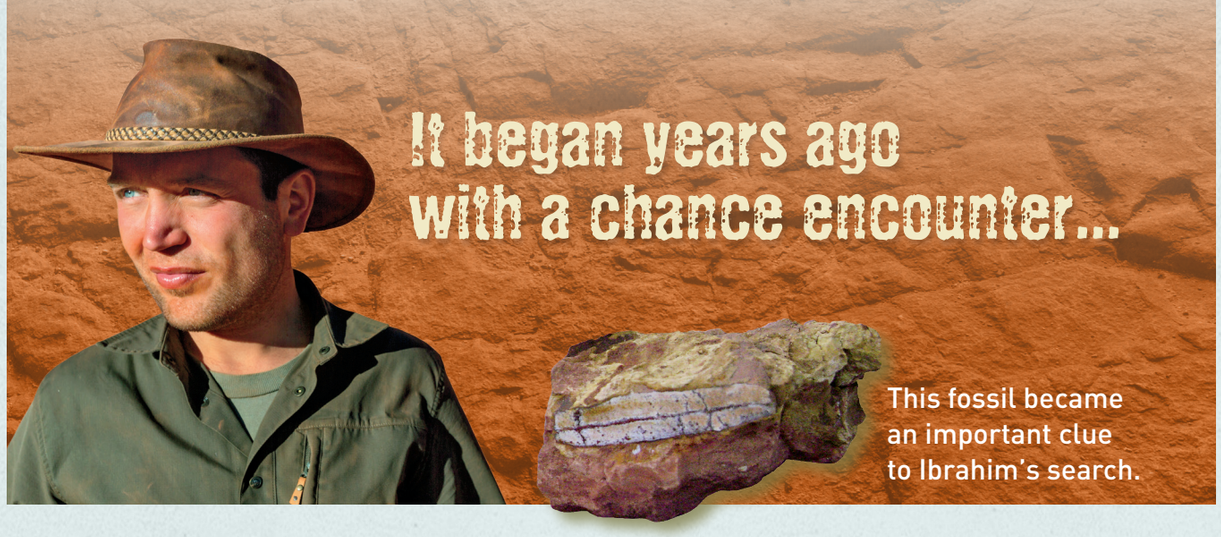
LIFE SCIENCE

As you read, think about what external structures of *Spinosaurus* led scientists to think it lived mainly in water.

Rethinking Spinosaurus

Follow a scientist's quest to reveal the secrets of this mysterious dinosaur.

By National Geographic staff



This fossil became an important clue to Ibrahim's search.

Nizar Ibrahim was in a small town in Morocco in 2008. He's a scientist who studies fossils—a paleontologist. He's also a National Geographic Explorer.

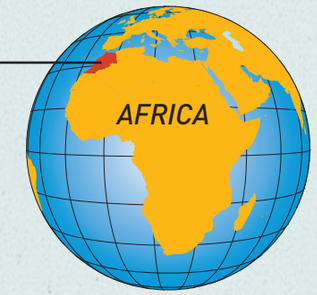
He had just finished collecting fossils in the nearby Sahara. He wanted to talk to some local fossil hunters. Perhaps, they had fossils that might provide clues to the ones he had found.

Ibrahim was approached by a man who had a box of fossils he had collected. The man had a mustache. Ibrahim didn't know how important that mustache would later become.

One fossil caught the explorer's eye. It was long and flat. He thought that it might be part of a spine or a rib. He thought it might be important, so Ibrahim bought the box.

Years later, that fossil would lead him on a journey. He would discover one of the oddest dinosaurs that ever lived.

Ibrahim used the fossils that had been found to piece together an unknown dinosaur.



Picturing the Past

Ibrahim uses the scientific process to piece together the past. He studies bones and **observes** their shape. Where were they found? What part of the animal did they come from? He asks questions to form a **hypothesis,** or explanation, for how these ancient animals used to live.

When Ibrahim looks out across the Sahara, he pictures what it looked like 95 million years ago. Instead of sand, he sees rivers and swamps. There were giant turtles, huge crocodiles, and fish the size of cars. Three of the world's largest meat-eating dinosaurs walked on land.

Something Urgent

One day, Ibrahim received a message from some paleontologists in Italy. They described some fossils they thought Ibrahim would want to see.

When he arrived, several fossils were laid out for him. The long, flat bones were in the basement of a museum. They were thought to have come from Morocco. They looked like the fossil he bought from the stranger years ago.

These bones reminded Ibrahim of something else, too. As a child, he had seen drawings and photos of a dino in a book. Could they be connected? He was starting to form a new hypothesis.

Searching for *Spinosaurus* took hard work and perseverance.

A Different Dinosaur

The bones Ibrahim remembered from the book had been discovered by a German scientist. He had uncovered these bones in the Sahara.

This dinosaur was bigger than T. rex. It had long jaws, sharp cone-shaped teeth, and a huge sail on its back. The scientist named it *Spinosaurus.*

Only two partial skeletons had ever been found. Both were destroyed during World War II. Only notes and old photos remained.

Ibrahim thought his fossil and the ones in Italy might be from *Spinosaurus.* He had to find that mustached-man!

On the Trail

It was crazy. Ibrahim knew that. Five years had passed. He didn't know the fossil hunter's name or address. All he knew was that he had a mustache. Still, if he could find the fossil hunter again, maybe he could find *Spinosaurus.*

Ibrahim traveled back to the small town in Morocco. Against all odds, he began his search. Days went by without success. Ibrahim's spirits sank. The task seemed impossible.

On his last day in Morocco, Ibrahim sat with two friends in a small café, sipping tea. Suddenly, he looked up. A tall man wearing white passed by his table. The man looked familiar, and he had a mustache

Ibrahim leaped up and chased after him. He caught up to the man and looked at his face. It was the fossil hunter! Now, if only the hunter would lead him to the fossils.

Ibrahim was led into the desert to find *Spinosaurus.*

Discovery!

The man with the mustache listened closely to Ibrahim. He agreed to lead Ibrahim to the place where he had found the fossils.

The next day, the two men drove a short distance into the Sahara. They would have to make the rest of the trip on foot. They climbed a steep slope. Near the top, they reached a small cave. This was where the fossil hunter had been digging.

Ibrahim gently picked away at some of the sand and rock. Within minutes, he discovered several bones. At last, he had found *Spinosaurus!*

Ibrahim works slowly and carefully.

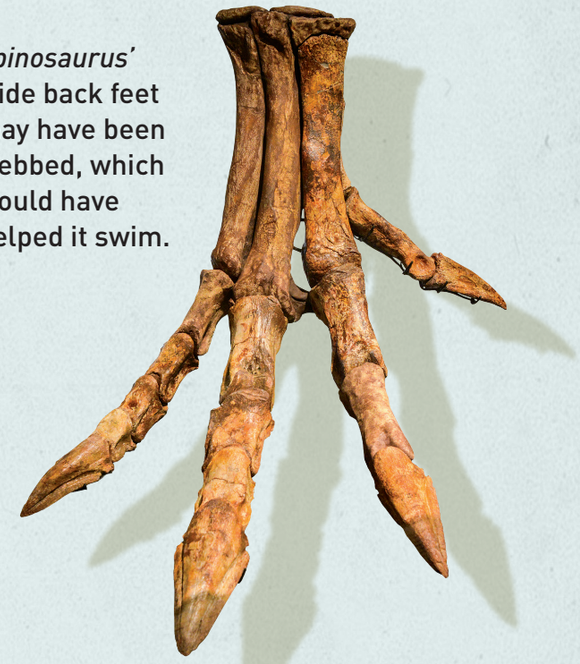
Building the Beast

Many large dinosaurs seemed to have lived in this area at the same time. Were they competing for the same prey? How was *Spinosaurus* able to live among other big predators? Ibrahim began to form a hypothesis.

To prove it, he had to conduct an **experiment** and recreate *Spinosaurus.* He didn't have all the pieces, but he had enough to get started. His **method** was to create a digital model on a computer based on what he knew.

With other scientists, he made a skin for his model skeleton. Now, he had a complete *Spinosaurus.* It looked different from all the other dinosaurs he had seen.

Spinosaurus' head was long and thin.



Spinosaurus' wide back feet may have been webbed, which would have helped it swim.

Making a Model

Spinosaurus' neck and body were longer than those of other dinosaurs. The *Spinosaurus* had short hind legs and powerful forearms. Its back feet were wide and flat. To Ibrahim, they looked like paddles.

Ibrahim studied *Spinosaurus'* skull. It had a long snout, but its nostrils were halfway up the skull.

Until Ibrahim had created this model, scientists had assumed that *Spinosaurus* spent most of its time on land. Seeing the way this dinosaur actually looked made Ibrahim realize that it probably didn't spend much time there.

Ibrahim made a **conclusion** that this dinosaur spent most of its time in water. Its long tail may have helped propel it through the water. *Spinosaurus* probably had webbed feet that it used to paddle. High nostrils allowed it to keep most of its head underwater while it hunted. This is why *Spinosaurus* could exist with the other meat-eating dinosaurs.

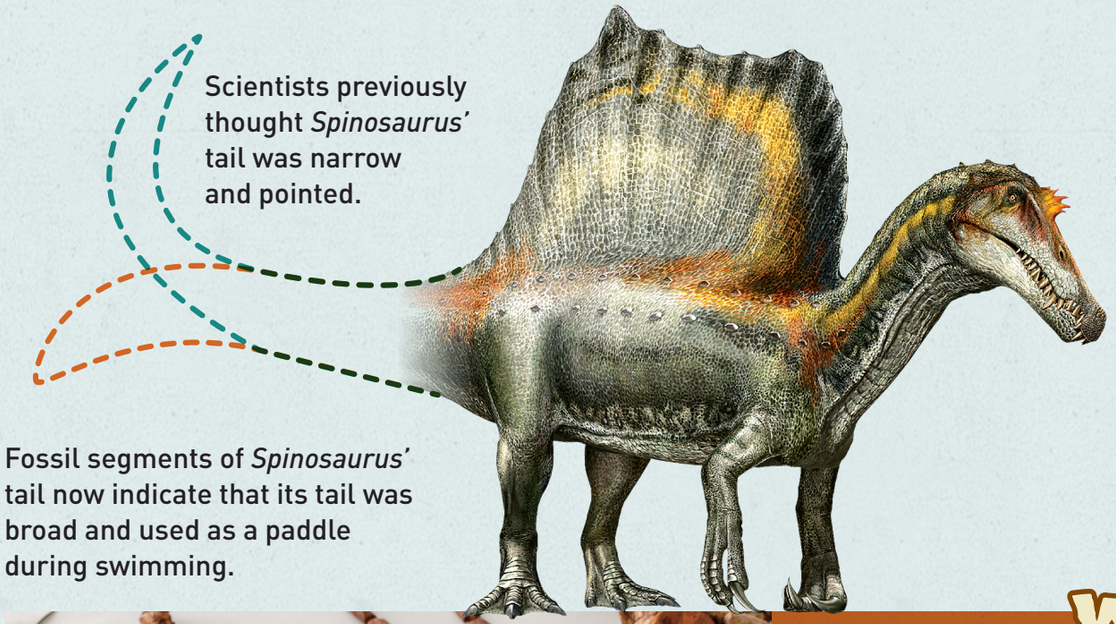
Life in Water

Not every scientist agreed with Ibrahim. So, with a grant from the National Geographic Society, Ibrahim searched for more fossils. The work was difficult. However, it became rewarding after the team discovered more pieces of a *Spinosaurus* tail.

In other dinosaurs, the tail narrows to a point. In *Spinosaurus,* the tail is broad. It looks like a paddle. Tiny bumps near the tail's end may have allowed it to move back and forth. Long, thin bones connect to the tail like the tailbones in a fish.

Ibrahim wanted to know how this tail might have worked in the water. Through digital modeling and a real model tested in water, he found out.

Spinosaurus' tail delivers more than eight times the forward thrust in water than the tails of other dinos on land. Now more than ever, Ibrahim was certain that *Spinosaurus* spent most of its time in the water.



Scientists previously thought *Spinosaurus'* tail was narrow and pointed.

Fossil segments of *Spinosaurus'* tail now indicate that its tail was broad and used as a paddle during swimming.

Scientists attempt to create a life-size model of *Spinosaurus,* showcasing what is now known about its tail.

Questions Remain

Research goes on. One of the other fossils may hold another important clue. It is a bone from the dinosaur's foot. With it, the team can recreate the whole foot. Ibrahim believes it was webbed. Good for an aquatic dinosaur.

Ibrahim continues to dig to find answers to his *Spinosaurus* questions. The more impossible the question, the more determined he is to answer it.

WORDWISE

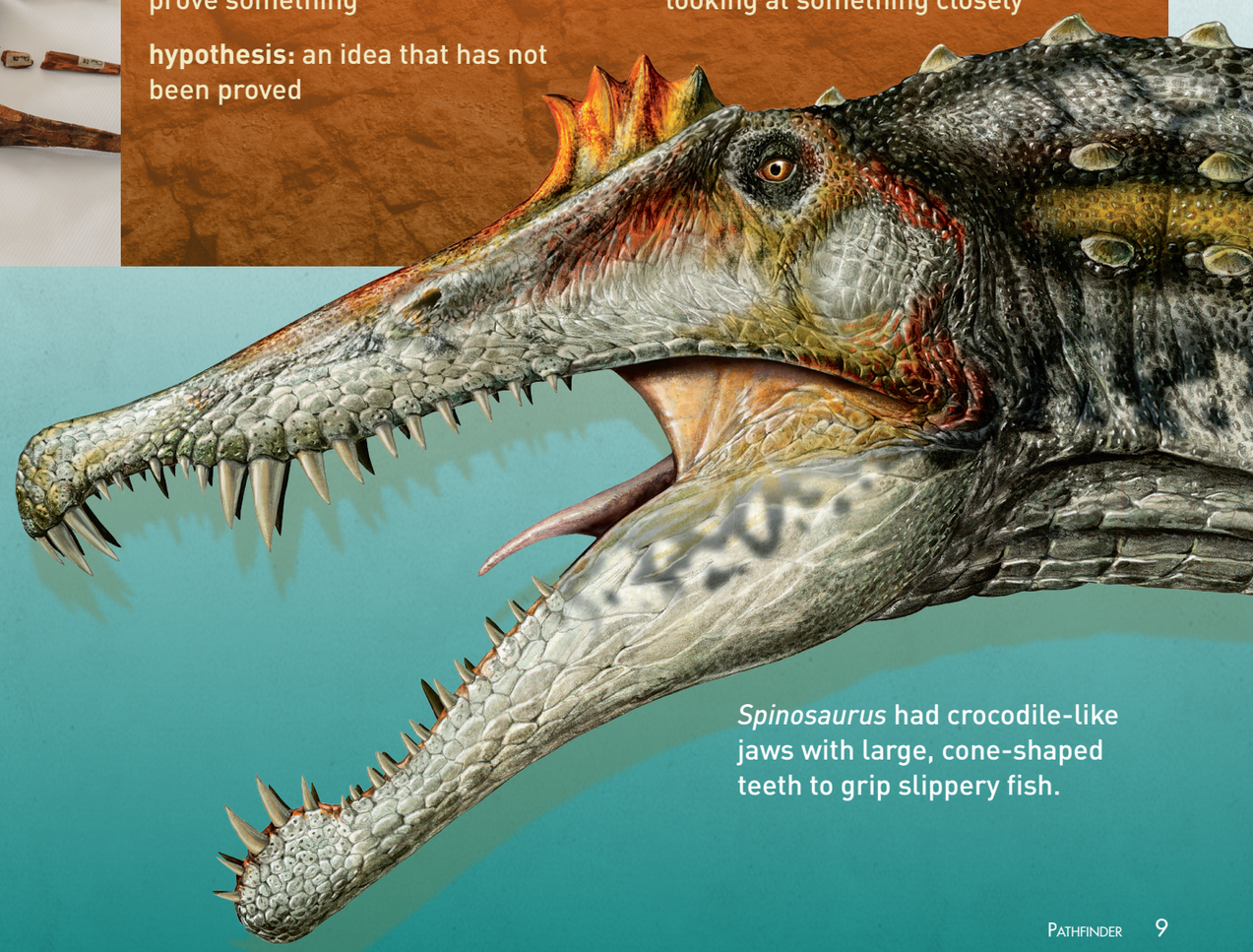
conclusion: an opinion formed after careful research and thinking

experiment: a test used to find or prove something

hypothesis: an idea that has not been proved

method: a step-by-step plan to find out if an idea is true or not

observe: to gather information by looking at something closely



Spinosaurus had crocodile-like jaws with large, cone-shaped teeth to grip slippery fish.

Wildlife and Wild Places

LIFE SCIENCE

As you read, think about how the food sources of the dragonfly change at different stages in this insect's life cycle.

Look at them side-by-side. They are different versions of the same thing!

Discover how a dragonfly transforms itself.

By Brenna Maloney

The Transformer

The older version has three body segments. Like all insects, it has a head, thorax, and abdomen. It has six legs. It has two pairs of wings. Its huge eyes are so close together on the top of its head, they touch. The colors of its body are brilliant.

The younger version also has three body segments. It has six legs, too. But its wings have not yet formed. Its eyes are set far apart. And it's not as colorful.

This is the same animal, the southern hawker dragonfly. You are just seeing it at different points in its life.

Changes Ahead

All insects undergo **metamorphosis**. This process of change takes place as an insect nears adulthood. More than 80 percent of insects experience **complete metamorphosis.** This happens in four stages: egg, larva, pupa, and adult. Dragonflies experience an **incomplete metamorphosis.** This happens in only three stages: egg, **nymph,** and adult.

Southern hawkers are one of the most common dragonflies in Europe. They live near small ponds and woodlands. Each dragonfly begins life as an egg.

Male and female dragonflies mate in late summer or early fall. The female lays her eggs, one by one, inside the stems or leaves of a water plant. This keeps them safe from predators.

To hatch in the spring, the young dragonfly swallows water through the casing of the egg. The egg then swells. A sharp pointer on the dragonfly's head pierces the egg. It bursts open.

A prolarva emerges and frees itself from its covering. It enters the water and sheds its skin. It is now a nymph.

A southern hawker nymph's body is brown and green. These colors make the nymph harder to see in water.

A southern hawker nymph's eyes are set far apart.

Nymphs must **molt,** or shed their skin, a number of times as they grow. That's because their outer layer, called an exoskeleton, cannot stretch or grow. When the insect gets too big for its skin, the skin splits open.

Deep breaths cause the split to widen. The southern hawker then shrugs out of the old skin. Now the dragonfly nymph is slightly larger.

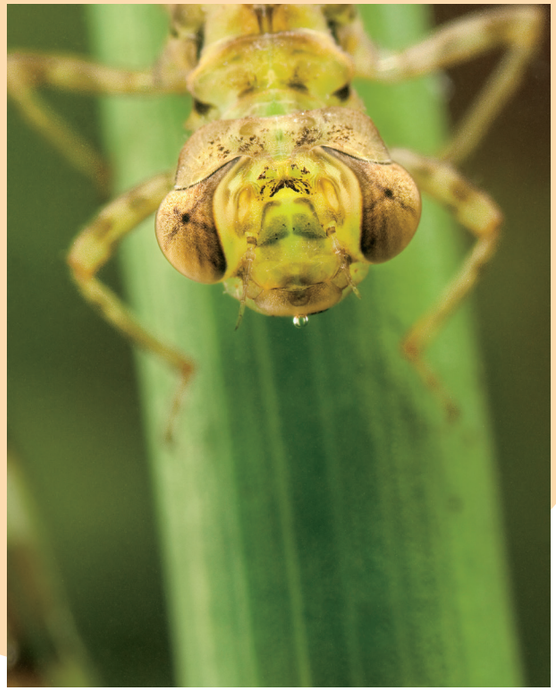
Molting is helpful in another way. It allows damaged tissue to heal. Missing limbs can regenerate, or grow again. Yet, molting can be a dangerous time, too. Until the new exoskeleton hardens, the dragonfly is exposed to predators.

More Mobile

A dragonfly nymph can zip through the water. It moves by squirting water out of its back end. This propels it forward. The dragonfly needs to move quickly because it is an active hunter.

The nymph's body is brown and green. These colors help it blend in with pond or lake water. It is hard for either its predators or prey to spot it. Yet, the nymph can see them quite well.

At this stage in its life, the southern hawker's large eyes are set far apart. Its eyes are always scanning for prey. The nymph needs to eat and looks for insects, small tadpoles, and fish.



When resting, the southern hawker nymph's lower lip is folded under its jaw.

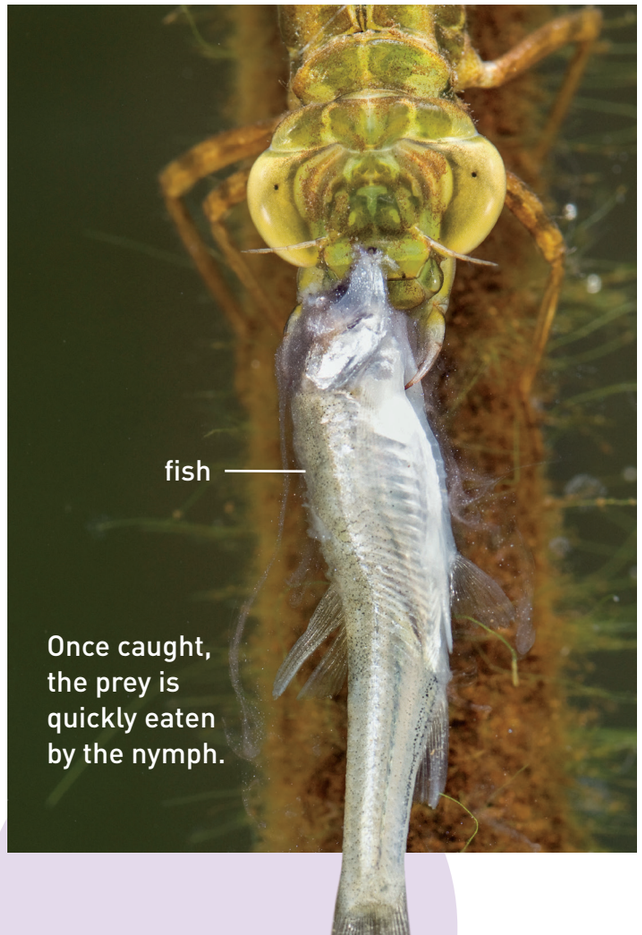
When hunting, the nymph shoots its lower lip forward to reach prey.

Catching Prey

As a nymph, the southern hawker has a special way of catching prey. It is able to fold its lip beneath its head when not hunting. When it sees prey, the lip shoots forward. Then it stabs the prey with sharp spines.

The lip can move in less than 25 milliseconds. Once the prey is impaled, the nymph pulls its lower lip back toward its jaws. The jaws are strong and tough and lined with teeth. They cut the prey into pieces.

As the nymph eats, it grows. And as it grows, it molts. A nymph may molt as many as eight times. The period of growth between each molt is called an **instar.** Life as a nymph is long. It can be as long as several years.



Once caught, the prey is quickly eaten by the nymph.

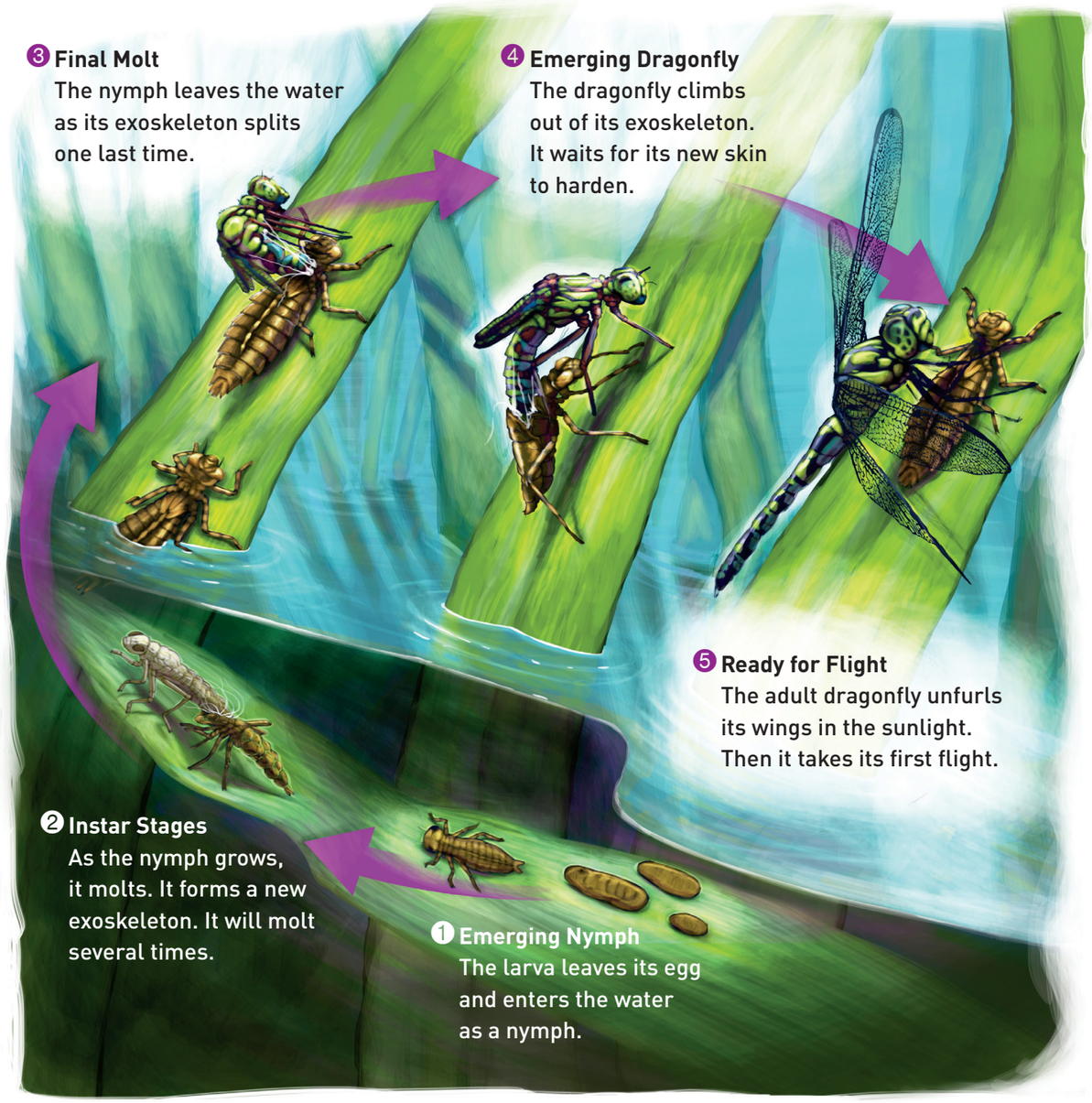
A Final Change

In the final stages of metamorphosis, the southern hawker's lower lip contracts. It can no longer hunt and eat. It needs to molt one last time. It waits until night before leaving the water. It climbs up the stem of a water plant.

The insect pumps fluids into its body. It starts to swell. The exoskeleton splits. It thrusts its body through this gap. Its head and legs follow. Then it slowly pumps fluids into the hollow veins of its new wings to expand them.

From Larva to Adult

Take a closer look at the journey of a dragonfly:



An adult southern hawker's eyes have thousands of lenses.

Dragonflies have six legs, but most cannot walk.

Females lay their eggs in the water.

In Flight

The dragonfly that you see flitting over fields looks different from its nymph form. The male dragonfly's black body is about 70 millimeters (2.8 inches) long. It is dotted with dashes of apple green and turquoise. Its bright colors are designed to attract a mate. Its two sets of wings stretch out 110 millimeters (4.3 inches) from its body.

In the insect world, the dragonfly's sight is unmatched. Its two compound eyes are made up of thousands of individual lenses. The front of each eye focuses on forward flight. The top of each eye searches for prey.

Dragonflies also have three simple eyes. Each has a single lens. These eyes form a triangle between the compound eyes. Nerves connect them to the dragonfly's flight muscles. They give information about the dragonfly's position relative to its prey.

The southern hawker uses its two sets of wings to fly forward, backward, or sideways. It can beat its wings together or move each one separately. To fly, the wings twist in a figure-eight motion. It can fly up to 54 kilometers (34 miles) an hour.

Focused Hunter

When the southern hawker hunts, it becomes a deadly predator. Its success rate is about 95 percent.

Its prey is caught and eaten "on the wing." That means, it is caught while the dragonfly is in flight. The ability to catch prey while flying at top speeds is a complicated process.

The dragonfly has to be able to predict where its prey will be. It must figure out the distance, the direction, and the speed of its prey. In milliseconds, the dragonfly plots its course.

The dragonfly holds its legs forward. The long spines on its legs grip the prey. Then the dragonfly bites off and discards the prey's wings before eating its body.

Eating and mating are an adult southern hawker's only two jobs. Within two months, the adults die. Their eggs are waiting, though, for the life cycle to begin again.

WORDWISE

complete metamorphosis: a process of change that takes place for an insect in four stages (egg, larva, pupa, adult)

incomplete metamorphosis: a process of change that takes place for an insect in three stages (egg, nymph, adult)

instar: the stage between molts of the exoskeleton

metamorphosis: the changes that occur as an insect transforms from an immature form to an adult form

molt: to shed an outer covering, such as skin, hair, or feathers, that is replaced by new growth

nymph: the immature form of an insect with simple metamorphosis

As you read, think about how this engineer has invented some solutions to Earth's trash problem.

TURNING TRASH INTO TREASURE

By Glen Phelan

Meet Arthur Huang. This architect, engineer, and National Geographic Explorer has some bold plans for Earth's mounting piles of plastic trash.

Building With Plastic Bottles

What could you do with one and a half million plastic bottles? Arthur Huang built a nine-story building with them! He called it the EcoArk. It's a special name for a special building in Taiwan, Asia.

The EcoArk is sleek and modern. It really catches the eye. You might think it's made of glass, with a pattern of white dots along the outer walls. Now look closely. Those dots are actually bottle caps from the plastic bottles that make up the walls.

The walls of the EcoArk are not made of ordinary plastic bottles, however. They are called Polli-Bricks. They are made of recycled plastic. The plastic was chopped up and melted down. Huang and his team invented a way to reshape and strengthen the melted plastic. He made a new type of building block shaped like a bottle.

The Polli-Bricks have grooves. They fit together tightly and lock in place. They are built into panels about the size of large windows. A coating helps protect them against fire and weather. The panels weigh one-fifth as much as glass panels. Yet, they are incredibly strong. This is due to the honeycomb pattern of the interlocking bottles.

These safety features are essential. Why? The EcoArk is in a part of the world that experiences extreme natural forces. Taiwan, an island off the coast of China, is rocked every year by earthquakes. Violent storms, called typhoons, batter Taiwan each summer. EcoArk braves it all with no damage.

Eco-Friendly

Huang designed the EcoArk to be **eco-friendly,** in other words, to not harm the environment. The Polli-Brick walls use plastic trash that would otherwise end up in landfills or in the ocean.

The Polli-Bricks are eco-friendly in other ways, too. The bottles are filled with air. Heat doesn't pass through air easily, so the bottles help keep heat from entering the building. That's key in Taiwan with its long, hot summers.

Most buildings use electricity for air conditioning. This comes from burning oil, coal, or natural gas at a power plant. Burning these fossil fuels adds carbon dioxide to the air.

The gases trap energy from the sun. This keeps our planet warm. That's the **greenhouse effect.** But burning too much fossil fuels has increased the greenhouse effect. Air temperatures have warmed in many places. Huang didn't want to add to that problem.

Huang's Polli-Bricks are made out of plastic bottles.

EcoArk

The grooved Polli-Bricks lock together to form panels.

The Polli-Brick panels are lightweight but strong. Huang proves this by jumping up and down on them.

A New Philosophy

Arthur Huang designs buildings to have the smallest **carbon footprint** possible. What is the carbon footprint of the EcoArk? It is zero!

The building runs without emitting gas. Even systems that require electricity, like fans and lights, get their power from wind and solar energy, not by burning fossil fuels.

Upcycling

The EcoArk is just one example of how Arthur Huang turns trash into treasure. He is sure most waste can be used to make something else. And the new product can be even more valuable. This is called **upcycling.**

To turn this idea into action, Huang started the company Miniwiz. Its motto is: "It is wise to minimize." The goal is to help people make their carbon footprint smaller. How? By using upcycled products. That will also reduce the amount of waste in the world, especially plastic.

The Sky's the Limit

What materials and products can be made from upcycled trash? The sky's the limit. Miniwiz created Polli-Bricks from plastic bottles. It has also developed a material from plastic waste to make wings for a one-person airplane. That really puts the "up" in upcycling!

What other wonders have come out of the "trash lab?" How about furniture made out of cigarette butts? They are the most littered item in the world! Sunglasses made from CDs. A box that holds sneakers can be refolded into a backpack.

Trashpresso

How do you change plastic garbage into a useful material or product? Sometimes, you have to invent a machine and a new way of doing things. That's what Miniwiz did.

Trashpresso is an assembly line of machines working together. First, they shred the plastic trash into flakes. The flakes are then washed, dried, and placed into molds. The flakes are pressed and melted into shape. Most of the shapes are six-sided tiles. People can use them to build walls, floors, or ceilings. Trashpresso has a zero carbon footprint. It doesn't burn fossil fuels. Instead, solar panels capture sunlight and turn it into electricity.

Trashpresso can go just about anywhere. This allows Huang to use his invention to educate people everywhere about the problem of plastic trash. He also inspires people to be part of the solution.

WORDWISE

carbon footprint: the total amount of greenhouse gases caused by a person or product

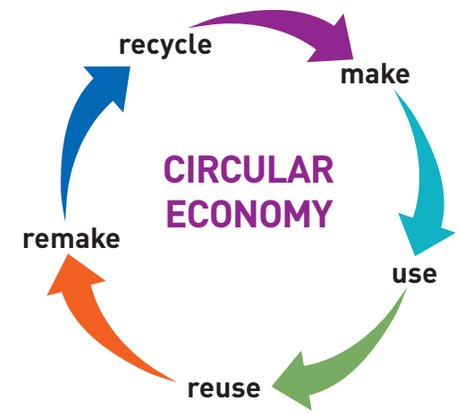
eco-friendly: not harming the environment

greenhouse effect: the trapping of heat by certain gases in the air

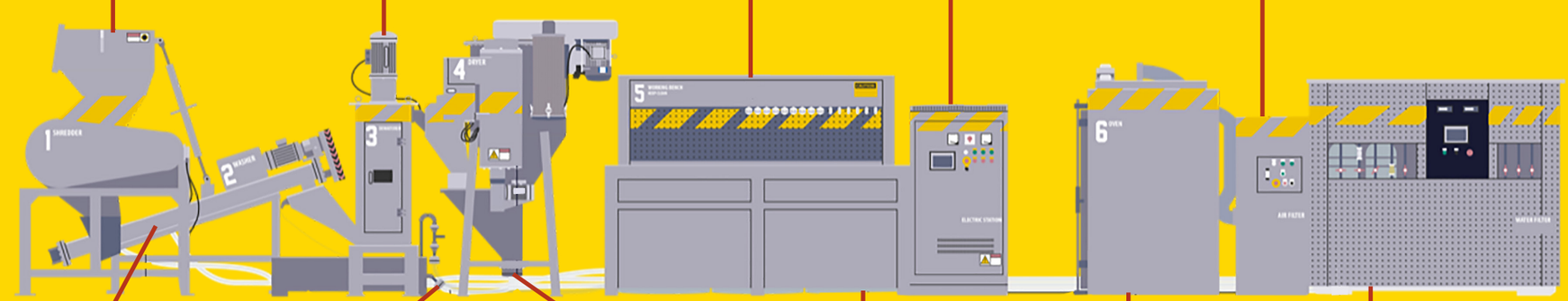
upcycling: recycling a material to make a product that is more valuable than the original

CIRCULAR ECONOMY

Most economies today are linear. This means resources are used to make a product. The product is used and then thrown away, producing waste and pollution. In a circular economy, waste is used as a resource. We use the product to make the product again or make another product. There really is no such thing as waste in a circular economy.



TRASHPRESSO



SHREDDER breaks down plastic trash into tiny flakes.

DEHUMIDIFIER dries the wet flakes.

WORK BENCH is where flakes are placed into molds.

ELECTRICAL STATION contains the electrical system to make the machine operate.

AIR FILTER prevents the release of poisons that might be produced during the melting stage.

WASHER cleans trash to remove impurities.

WATER PIPING carries dirty water away.

DRYER further reduces moisture.

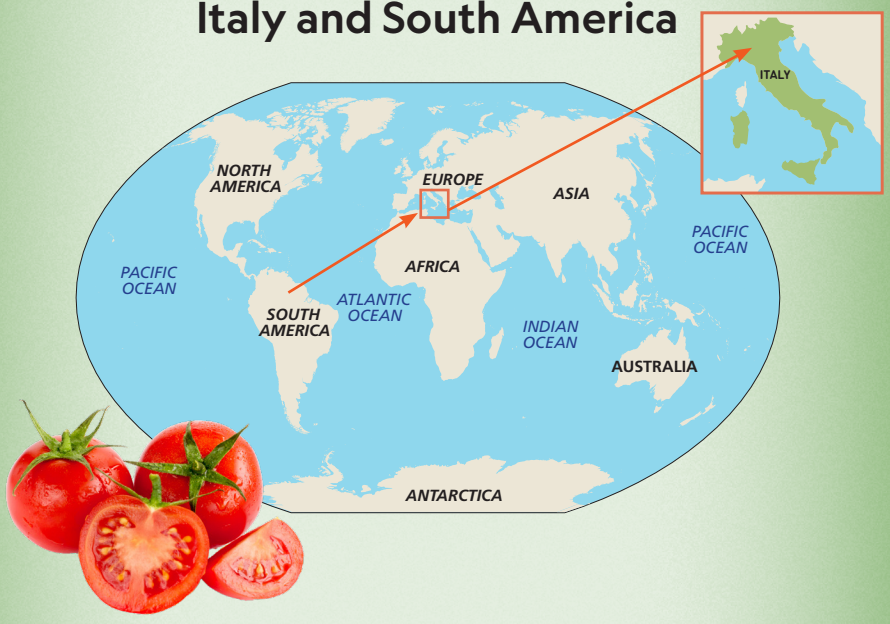
WATER TANKS store water for the process.

OVEN is where flakes melt in their molds, forming finished tiles.

WATER FILTER purifies the water and cycles the water back through the system.

NATIONAL GEOGRAPHIC | THAT'S GEOGRAPHY

Connections:
Italy and South America



Italians are known for using tomatoes in their cooking. Think of pizza and pasta sauces. But, if you think the tomato is from Italy, think again! It is believed that tomatoes came from South America and were first brought to Europe by Spanish explorers in the 15th century. At first, tomatoes were used for decoration, as Europeans loved their color. However, tomatoes grew well in the warm Mediterranean climate, and by the 16th century, they were being used by Italian cooks. So, if you love tomato sauce on your pizza, you have South American farmers from long ago to thank.

Keep learning with the National Geographic Education Community!

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NATIONAL GEOGRAPHIC EXPLORER (ISSN 1541-3357) is published five times during the school year—September–October, November–December, January–February, March, and April—by National Geographic Society, 1145 17th Street NW, Washington, D.C. 20036. Postmaster: Please send address changes to Attn: Explorer Magazine, National Geographic Society, PO Box 291875, Kettering, OH 45429. Periodical postage paid at Washington, D.C., and additional mailing offices.

Cover: a southern hawker dragonfly
8/20/QGL/1

SEPTEMBER/OCTOBER 2020

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