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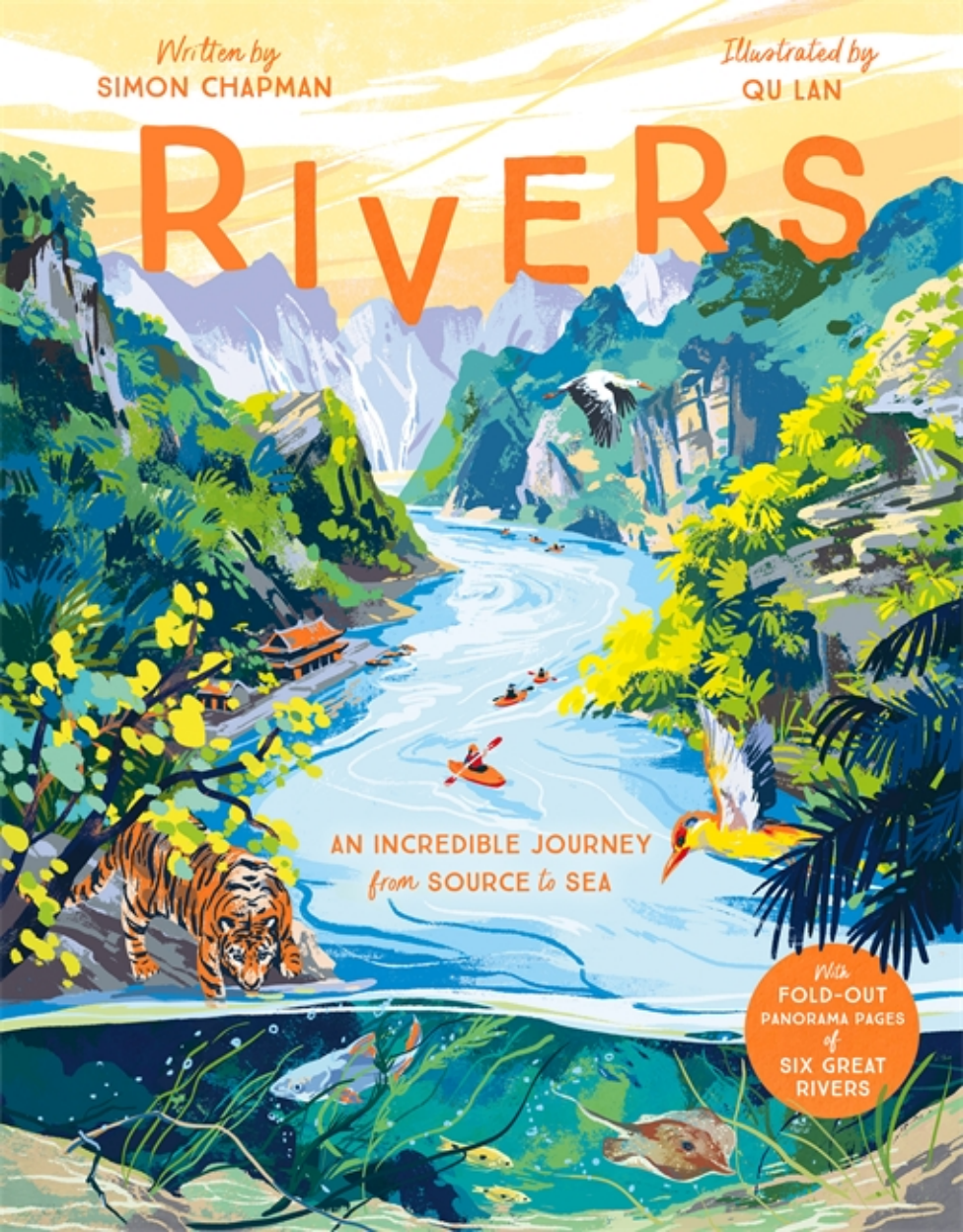
RIVERS



AN INCREDIBLE JOURNEY
from SOURCE *to* SEA

With
FOLD-OUT
PANORAMA PAGES
of
SIX GREAT
RIVERS

A World of Rivers

A RIVER MEANDERS THROUGH A VALLEY, its surface rippling as it sweeps around each curve. Fed by rain that falls high in the hills, our river has been winding its way down to the sea, growing ever wider and stronger. Over millions of years, its water has cut a valley in the land and dropped mineral-rich mud along its edges, creating marshy wetlands and floodplains where forests have grown and crops have been farmed. Above and below the river's surface, its waters are teeming of life, too. They are home to fish, as well as many animals that hunt them. [Wrap up sentence for intro to lead into read of spread and book]

With fertile land to farm, fish to catch, and a natural, shallow crossing point, settlers found this was a good place to live. First, they built villages on both sides of the river, crossing to trade food and goods by wading or rowing in small boats. Later, they built bridges to cross. The river allowed them to travel upstream or down to the sea. In time, the village grew into a town and a castle was built to defend it and to control who could use the crossing place. The town grew into a city.

All of this – the landscape, the wildlife and the city – is here because of the river. In every river's journey, streams meet, join and grow. From the vast Amazon in South America and the colossal Nile in North Africa to the 32-kilometre-long River Onyx in Antarctica, rivers are constantly shaping the Earth, bringing life and delivering fresh water.

Today in Cochem on the River Rhine, the castle still stands and there are more bridges. The river has been dug deeper for bigger boats to pass, and some of its flow has been diverted for use in factories and to water crops. But the river itself has barely changed.

Water

EVEN THOUGH RIVERS BEGIN IN HILLS AND MOUNTAINS, their water comes from the sea. The sun's energy evaporates sea water into the air, which cools to form clouds. When the clouds drop rain or snow onto the land, rivers take this water downhill to the sea. The whole journey from sea to clouds to river and back to the sea to complete the loop is called the water cycle. Here's how that happens.

1. The sun's energy evaporates water from the sea and other water sources as water vapour (a gas). Plants give out water vapour too.

2. As the water vapour rises it cools and condenses (turns back in to water) to form clouds of tiny water droplets.

3. Winds blow the clouds inland.

4. When winds blow clouds high up mountainsides they cool. This makes more water vapour condense and the water droplets grow bigger and heavier.

5. The water falls to earth as precipitation – rain, hail or snow.

The area of land where all the water flows into one river system is called the river's **catchment**.

6. The force of gravity pulls this liquid water down streams and rivers, back to the sea.

This white dashed line shows the **watershed** – the divide between two river systems. Any rain or snow falling on the far side of this mountain ridge will flow into a different river system.

7. The river meets the sea.

WHAT IS WATER?

Each molecule of water (H_2O) contains two hydrogen atoms and one oxygen atom bonded together. These molecules can flow around each other and stay close together, and, because of this, water can change its shape.

Water is HEAVY!
One cubic metre weighs one tonne – about the same as a small car. The largest river in the world, the Amazon, moves over 200,000 tons of water every second. The much smaller River Thames in London, UK, shifts just 66 tons of water every second.

Water is FAST!
Most rivers flow at a speed of around 3 metres per second – that's about how fast you run. Rivers in flood after heavy rain flow even faster.

Water is POWERFUL!
Because it is heavy and can flow easily, moving water can push with a lot of force. It can break rocks into tiny particles and carry objects along with it. Over millions of years, it can wear down mountains.

SOURCE:
A River Begins

HIGH IN THE MOUNTAINS, warmed by the sun's rays, ice melts. Water drips down and trickles into a pool, which grows into a small lake. When this overflows, a stream forms. The lake is this river's source.

The source, also called the headwaters, is where a river starts.

In a week or a month or a year, and maybe thousands of kilometres away, water from this stream will reach the sea. By then it will have been joined by other streams, raced down mountainsides, leaped over waterfalls and swirled around river bends. Along the way, some of its water will have flooded out over the land and soaked into the soil or got trapped in marshy wetlands where the river lost its way. Some of its water will have been evaporated by the sun, and rained or snowed down to start the journey all over again, most likely in a different place and in a different river.

This is Mount Makalu in the Himalayas, the starting point of the River Ganges.

SPRINGS

Many headwater streams flow straight out of the ground. These happen when rainwater soaks down into the ground and later bubbles to the surface when it reaches underground rock that it cannot pass through. The source of the River Thames in the UK is at a springs 150 kilometres west of where the Thames reaches the sea.

Rainwater soaks into the ground...

And finds its way down through the soil, and gaps and cracks in rocks...

Until it is blocked by a layer of impermeable rock, which it cannot get through.

The groundwater (underground water) trickles along the hard rock layer until it breaks through the surface again.

Sometimes underground lakes, called aquifers, form.

Heading Downhill

STILL IN THE MOUNTAINS, BELOW THE HEADWATERS NOW, the young stream moves quickly and wears away the ground as it flows. It may take years to carve out the slightest dent if the rock beneath it is hard, like granite, but just months if the rock below is soft and crumbly, like chalk or sandstone. As the stream heads downhill through the mountains, its water breaks off pieces of the rock. Grit and small pebbles are swept along in the current. Larger stones roll or bounce along the stream bed. Now there is not just the force of the water cutting into the ground, but also the momentum of the load it carries with it.

CARVING VALLEYS

In its upper course, the river takes the steepest, quickest route downhill, eroding its riverbed downwards. Over thousands or millions of years, a river can carve out a steep-sided channel, called a V-shaped valley, in the earth. If the rock the water flows over is all the same type, the valley is straight, but when when it flows over harder areas of rock or hits boulders that are too big to move, the river changes direction. Though the water is moving quickly in this part of the river's course, there is not enough of it – yet – to be able to cut through or push away large rocks. The result is that the river weaves from side to side as it speeds downhill. From above, the river's route is a zigzag, with sharp turns that weave around ridges of harder ground called interlocking spurs.

Tumbling over rocks and constantly in motion, the water dissolves oxygen from the air. Plants and animals that live in the upper course of the river have to be able to grip on tightly, so they don't get washed away.

The mountain stream runs clear. The water is not carrying enough mud particles to give it any colour yet.

Torrent ducks are experts in fast-flowing water. They plunge underwater to feed on insect larvae.

This small rock pieces bash together as they are carried along, chipping off their edges, becoming rounder and smoother. This is called **attrition.**

Algae waterweed clings onto the stones.

Stonefly larvae have flattened bodies and hooked claws to help them hold onto rocks.

Blackfly larvae cling on using hooks on the rear of their bodies. They also have a silk anchor line that stops them getting swept away if they come loose. Feelers around their mouth grab nutritious particles from the rushing water.

Waterfalls

RACING ALONG IN ITS UPPER COURSE, the river erodes a channel into the rock beneath it. If the water breaks through into softer rock below, it suddenly erodes downward more quickly and steeply, sometimes? leaving a ledge of hard rock. This is how waterfalls form. Whether they drop just a few metres, or nearly a kilometre like at Angel falls in Venezuela – the highest falls in the world, waterfalls are always spectacular.

At the breath-taking Jim Jim falls in Australia's Northern Territory, the Jim Jim River plunges 200 metres from a plateau of hard rock into a narrow, steep-sided valley called a gorge below. In the rainy season, when the water flow is highest, the river thunders over the edge into a pool below. Spray fills the air and shimmers with rainbow colours in the sun's rays. During most of the dry season, the falls does not flow.

1. Waterfalls form when rivers flow over hard then softer rock.

2. The river erodes its way downwards, steeply at first, until, eventually, it falls straight down.

3. Where the falling water hits the ground it wears away the rock, forming a deep pool called plunge pool.

4. The erosion of the soft rock leaves an overhang of hard rock. It breaks off falls into the river when its weight is no longer supported, and gets broken into smaller pieces by the force of the water.

5. Over time the waterfall erodes backwards and forms a gorge (see page 22). This is what has happened here at Jim Jim falls.

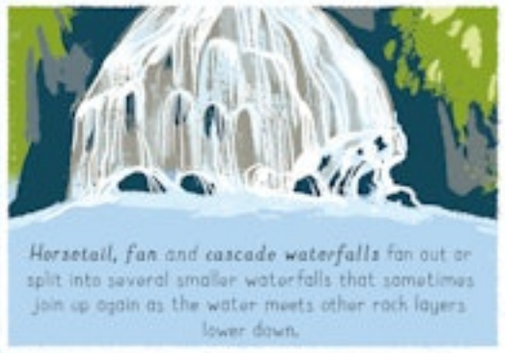
TYPES OF WATERFALL

Jim Jim Falls is called a plunge waterfall because the water drops without touching the rock on the way down. But there are other types of waterfalls that form depending on the hardness of the rock layers the river flows over.

Block waterfalls have a rectangular shape. The river drops over the edge as a wide sheet of water, like at Victoria Falls on Southern Africa's Zambezi river.

Water-chutes happen when a river is forced through a narrow gap between hard rocks. Water spurts through with extreme pressure and force.

Punchbowl waterfalls have a narrow channel that drops straight down and a wide plunge pool below.



Horsetail, fan and ***cascade waterfalls*** fan out or split into several smaller waterfalls that sometimes join up again as the water meets other rock layers lower down.

NYAMINYAMI: THE RIVER GOD OF THE ZAMBEZI

Victoria Falls on the River Zambezi in Southern Africa is the world's largest waterfall. Thousands of tons of water flow over the 1.5-kilometre-wide ledge every second, fall 100 metres before slamming into the solid rock floor. The constant rumbling in the rocky gorge below inspired the waterfall's name given to it by the local Kololo-Lozi people – *Mosi-oa-Tunya*, which means 'The Smoke that Thunders'.

Nyaminyami pendant

Downstream of the falls, the Zambezi has a series of dangerous whitewater rapids. The local people wear pendants carved into the shape of Nyaminyami, their river god – a serpent with a fish's head – for protection against drowning.

Son Doong cave in Vietnam, Southeast Asia, is the world's largest natural cave. It has a 3-kilometre-long river flowing through it, in total darkness except for two places where the cave's roof has collapsed where sinkholes have formed. Here, the sunlight can shine through, and islands of rainforest have grown upwards. The river flows past these back into the dark cave, until it exits into daylight through a hole in a cliff face. From there it carries on flowing [direction?] towards the Mekong River. The mystery here is not where the water goes to, but where it all comes from. It's thought there might be another, even bigger cave – as yet undiscovered – with another underground river upstream, feeding its water into Son Doong.

If the roof collapses between these sinkholes, a steep-sided river gorge might be formed.

Underground Rivers

SOME RIVERS FLOW UNDER THE GROUND. This happens most often in areas of limestone rock. Over thousands of years, rainwater corrodes (eats away) soft limestone as it seeps into cracks in the ground, creating caves and tunnels. When rock has been eroded away underground, the surface layer can collapse to make a sinkhole, which water tumbles into. When this underground water reaches another hard rock layer, it flows along on top of it until it breaks out of the ground again as a spring (see page 15).

Rainwater becomes slightly acidic when it dissolves carbon dioxide in the air, which dissolves limestone rock.

CAVE RIVER LIFE

Weird wildlife has evolved in many subterranean rivers. With no light, there is no reason to have eyes to see with, or bright colours to make yourself seen by others.

Kentucky cave shrimp *(Palaemonias ganteri)*
Location: Mammoth Cave National Park, Kentucky, USA
Size: Up to 3 centimetres long
This shrimp is transparent and has long feelers that help it to find its way around.

Cave fish *(Dracaonectes narinosus)*
Location: Found in one cave in Halong Bay, Vietnam
Size: 15 centimetres long
A type of loach, these small fish have no eyes and no scales on their bodies.

Cave fish *(Sinocyclocheilus)*
Location: China
Size: Up to 23 centimetres long
This fish has a highly developed sense of taste with many tastebuds in its mouths.

Olm *(Proteus anguinus)*
Location: Slovenia, Europe
Size: 20–30 centimetres long
An eyeless, white cave salamander, the olm has extra-sensitive hearing and smell.

GORGES:
The Grand Canyon

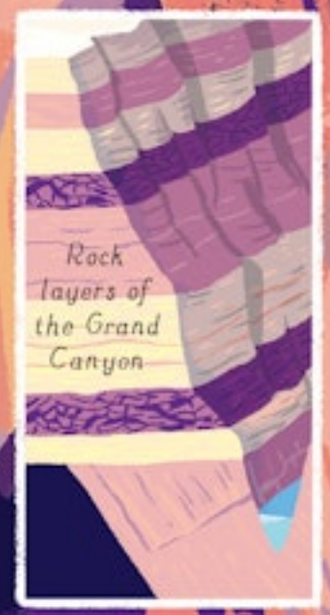
THE MOST FAMOUS GORGE IN THE WORLD, the Grand Canyon winds its way through the semi-desert of the Southwestern United States. It is 1,600 metres deep and over 400 kilometres long, carved by the Colorado River. The Paiute people of the Great Basin Desert area call it the Kaibab, which means the 'mountain turned upside down'. But the Colorado is no great Mississippi or Amazon. It is only 100 metres wide on average as it passes between the canyon's rock walls. So how did it cut so deeply into the earth?

The River Colorado is only 23 metres wide at its narrowest point in the Grand Canyon. That's about the length of a town swimming pool. But at this point, the river is also at its deepest – 25 metres.

Gorges are formed by waterfalls eroding backwards, caverns collapsing or by the sheer force of the water eroding through rock, and this takes time. Six million years in the case of the Grand Canyon!

The sedimentary rock that the Colorado River flows over is made of compacted sand and mud that was once at the bottom of the sea. This seabed was raised higher by the same earth movements that raised the land to form the nearby Rocky Mountains.

For most of the year the Colorado hardly erodes the rock beneath it. Virtually all of its downwards cutting happens when snow in the Rockies melts each spring, swelling the river to many times its usual size.



Rock layers of the Grand Canyon

Carrying 500,000 tons of tiny broken rock pieces, the floodwaters of the Colorado act like sandpaper, eroding the riverbed deeper and washing away the valley sides.

Water erodes hard and soft rock away at different rates, which has created the Grand Canyon's distinctive steps.

In the past, before people built dams across the Colorado, nearly 40 times as much water flowed through the canyon during its spring floods. Sometimes these floods washed fossils from the canyon walls all the way to the where the river meets the sea over 300 kilometres away.

Swirling currents can cause rocks, pebbles and sediment to erode circular hollows called potholes in the riverbed.

"A PERFECT HELL OF WAVES"

The Colorado River was first explored in 1869 by a 10-man expedition led by geologist Colonel John Wesley Powell. They set off in four wooden rowing boats, not knowing what they would discover. Over three months and 1,500 kilometres they encounted hundreds of rapids, one of which they described as "a perfect hell of waves". After one of the boats was smashed to pieces, three of the team deserted to take their chances in the desert. They were never seen again. The three remaining boats made it through the canyon and Colonel Powell became famous for his achievement. Powell took another expedition through the Canyon in 1871, this time with cameras and equipment to map the river's course.

RAPIDS:
The Everest of Rivers

JUST OVER A HUNDRED YEARS AGO, nobody knew where Tibet's Yarlung Tsangpo River went after it dropped into a gorge so deep, with rapids so dangerous, that none dared enter. Expeditions were sent to find out, but none succeeded. In 2002, satellite imagery showed what was really there.

The 'Great Bend' of the Yarlung Tsangpo has been called 'The Everest of rivers' due to its colossal size. Weaving around the Himalayan mountains of Gyala Peri and Namcha Barwa, the gorge here is over 5,300 metres deep – more than three times deeper than the Grand Canyon. Its water flows down a much steeper slope too. Over 240 kilometres, the Yarlung Tsangpo descends 1,400 metres, tumbling down the fiercest whitewater rapids in the world. Kayakers grade rivers on a scale of 1 (easy) to 6 (extreme). Within its gorge most of the Yarlung Tsangpo is graded 5 and above.

Rapids are shallow rocky parts of the river with turbulent flow. The water is extremely rough, swirling, splashing and mixing with air to creating frothy white water. They are a bit like waterfalls but they drop in steps more gradually, with the water travelling further horizontally than vertically. Even in their chaos, there are features that every rapid has.

Whirlpools happen where currents that are going in opposite directions meet.

Eddies are areas of swirling water that form behind obstacles such as boulders.

The V ripple shows where the water slides down.

***Stoppers**, also called holes, occur where the river flows over large submerged boulders or objects. This water on the other side dips down and tumbles back on itself over and over. Objects (including kayakers) can get trapped in stoppers.*

***Standing waves** happen where the water bounces back on small submerged rocks to form a line of spikey waves that stay in one place.*

LIQUID THUNDER

In 2002, a team of seven expert kayakers became the first people to descend the Yarlung Tsangpo's rapids.

With expert Tibetan mountain guides called Sherpas helping to carry their gear, the team made their way to the river, carrying their boats across snowfields to get to one of the sections.

The water, fed by glaciers from the mountains above, was icy cold and the kayakers knew that falling out of their boats was not an option. Even if they could escape drowning, hypothermia would prove fatal.

For 45 days, they trekked the gorge and kayaked the river, zigzagging through 'boulder gardens', dropping over waterfalls and surviving being pinned against cliffs and rolled in the flow.

When the team made it to a remote wire footbridge across the river, they pulled their boats out.

To this day, the last 50-kilometre-long stretch is still unexplored. The water so rough and the valley walls so steep that no one has ever been down it by boat or even seen what the river there looks like.

DAMS:
Holding Back the Water

THE FLOWING WATER OF A RIVER is powerful enough to move rocks and carry them along, and erode the land into valleys and gorges. Centuries ago, people realised that if they could harness this force, they could use it to power machines.

Since the fourth century BCE, people have built dams to block rivers. The earliest dams held back the water to keep a supply or they redirected the flow to irrigate crops. Using more complex dam designs, the ancient Romans channelled water to spin wheels to grind grain into flour, saw wood and stone, and hammer metal into shape. Today, we have the ability to build mega-sized hydroelectric dams, which use the power of water to generate electricity.

HOW IT WORKS

The gravitational potential energy of the water in the lake is used to turn the turbines when the water flows through pipes in the dam. The turbines turn generators. These are massive coils of wire which spin inside electromagnets to make an electric current flow.

When the dam was built, NASA calculated that 40 billion tons of water stored behind the Three Gorges Dam slightly slowing the rotation of the Earth and lengthened the Earth's day by 0.06 microseconds.

MEGA DAM

The Three Gorges Dam sits on the upper course of the Yangtze River in China – the third longest river in the world. The 2.3-kilometre-long dam has created a huge 660-kilometre-long lake behind it. When the water flows through the dam's 32 turbines, enough electricity is generated to power millions of homes. Once a hydroelectric dam has been built, no fossil fuels are burned to generate the electricity, which means no climate-harming gases are released into the air. But, as with all dams built across rivers, there are environmental costs involved.

DAMS: THE ENVIRONMENTAL COSTS

Boat lift

ADVANTAGES

FLOODING IS REDUCED DOWNSTREAM: Spring floods in the mountains had often washed away villages and farms in the Yangste's valley. The floodwater now gets trapped in the lake.

BOATS CAN TRANSPORT GOODS FURTHER INLAND: Large cargo ships are carried from the river below up to the lake by a special lift.

NO AIR POLLUTION: The generation of hydroelectricity does not release harmful gases into the air.

DISADVANTAGES

DESTRUCTION OF HOMES: The flooding of river valleys to form the lake destroyed entire cities, towns and villages. More than one million people had to be relocated.

RIVER WILDLIFE IS AFFECTED: Fish can no longer migrate up and down the river, causing fish populations to decline and affecting other animals that rely of them for food. The baiji river dolphin, found only in the Yangtze, is thought to have become extinct.

SEDIMENTS GRADUALLY FILL UP THE LAKE: When flowing water slows down and comes to a stop behind the dam, the particles of rock it has carried settle as mud on the lake bed. Unless this mud is removed, the turbines will eventually stop working.

Caption/label here for roundel

The Danube, Europe

THE RIVER DANUBE CROSSES EUROPE From Germany in the west to Romania in the east, running through ten countries – more than any other river in the world. Since the beginning of historical time, it has become a major route for travellers, traders and armies, leading into the heart of Europe, but it has also been a barrier that people have built hundreds of bridges across.

Árpád Bridge
Built 1950

Margaret Bridge
Built 1876 (rebuilt 1948)

Szechenyi Chain Bridge
Built 1849

THE CITY OF BRIDGES

The Danube runs through the heart of the bustling Hungarian capital, Budapest. United as one city in 1873, Budapest was two towns – Buda on the west and Pest on the east, first settled around 2,000 years ago. High up on a hill on the Buda side of the river is the fortified citadel, built in the first to protect the city and its bridges from invasion. Today, new and old buildings line both banks. There are homes and shops, and on the east side of the river a huge covered market and a palace of government built in the nineteenth century. Nine bridges now link Buda and Pest.

Elisabeth Bridge
Built 1903 (rebuilt 1964)

500 kilometres down the river...

THE FIRST DANUBE BRIDGE

Two thousand years ago, the Roman Empire set out to invade Dacia (modern-day Romania), but the Danube stood in its way. In 101 CE, Emperor Trajan and his legions crossed the Danube in wooden boats. The Romans defeated the Dacians, but they could not hold onto their newly conquered territory without more troops and supplies. In 105 CE, Trajan readied his army for another invasion but this time he ordered for a bridge to be built across the river. The Bridge of Apollodorus, named after its architect, had more than 20 arches and was 1,135 metres long. It was the longest river bridge in the world, and held that record for 1,000 years, but it was washed away by floods 165 years later.

The story of the Dacian wars is depicted in a carved frieze that spirals up a stone column, which still stands in Rome today.

Continent: Asia
Length: 2,5210 kilometres
Source: The Himalayas
Mouth: Bay of Bengal
Drainage basin: 1,016,124 square kilometres

1. Gangotri Glacier
The main source of the Ganges is a stream that gushes out of an ice cave in at the foot of the glacier

2. Mount Khailash
Another source of the Ganges. In the Hindu religion, this mountain is the home of the God, Shiva.

3. Haridwar
This holy city is one of the sites of the Hindu religion's Kumbh Mela festival, which is the biggest gathering of people anywhere on Earth.

5. New Delhi, *the capital of India, is on the Yamuna River, one of the Ganges main tributaries.*

6. Allahabad *is located where the Yamuna flows into the Ganges. On some years, the Kumbh Mela festival is held here.*

8. Patna *was founded in 490 BCE and is one of the oldest continuously inhabited places in the world.*

4. The Ganga Canal
This canals takes water from the Ganges to irrigate farmland between the Ganges and Yamuna rivers. The canal's branches have a combined length of 9,575 kilometres.

7. Varanasi
Hindu pilgrims flock to this holy city to bathe in the Ganges, give offerings to their gods and scatter the ashes of their dead.

10. Kolkata, *India's seventh largest city, spreads over the marshy land beside the Hooghly River, a distributary that has split away from the main River Ganges*

9. Meeting of the Rivers Ganges and Brahmaputra
(In Tibet, the Brahmaputra is called the Yarlung Tsangpo – see page xx.) From here both rivers' combined waters split into smaller 'distributary' rivers which flow into the Sundarbans.

11. The Sundarbans *is the largest river delta in the world. Fifty-four of its 102 islands are inhabited. The others form a wilderness of mangrove swamp forest, one of the last strongholds of the rare Bengal Tiger.*

Making Lakes

THIS KIDNEY-SHAPED POOL OF STILL, CLEAR WATER sits close to the Djidji river in Gabon, Central Africa. The air is filled with the hum of mosquitos and occasional plopping sounds as fish surface. There are tracks of otters and herons and the tail-slide marks of crocodiles that have slipped into the water to feast on the fish trapped here. This is an oxbow lake, formed when the river changed its course.

When looking from above at parts of the Amazon and Mississippi, old 'C' shaped oxbow lake scars can be seen overlaying each other, each shape an outline of where the river used to flow.

The fish are gulping air because the water holds less dissolved oxygen than in the cooler river channel nearby.

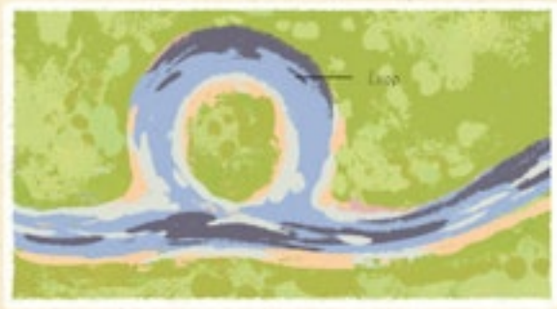
Otter and heron tracks on the bank of the oxbow lake

It is called an 'oxbow' after the shape of the collar put around an ox's neck when oxen used to pull ploughs.

HOW THEY FORM

1. As faster water at the outside of a river's bends erodes land away and slower water on the inside edges deposits sediment, a river's meander becomes more curved over time.

2. Eventually, water breaks through the narrow neck. The meander has bent around to meet itself, creating a loop. The land inside the loop becomes an island, completely surrounded by water, but it does not stay an island for long.

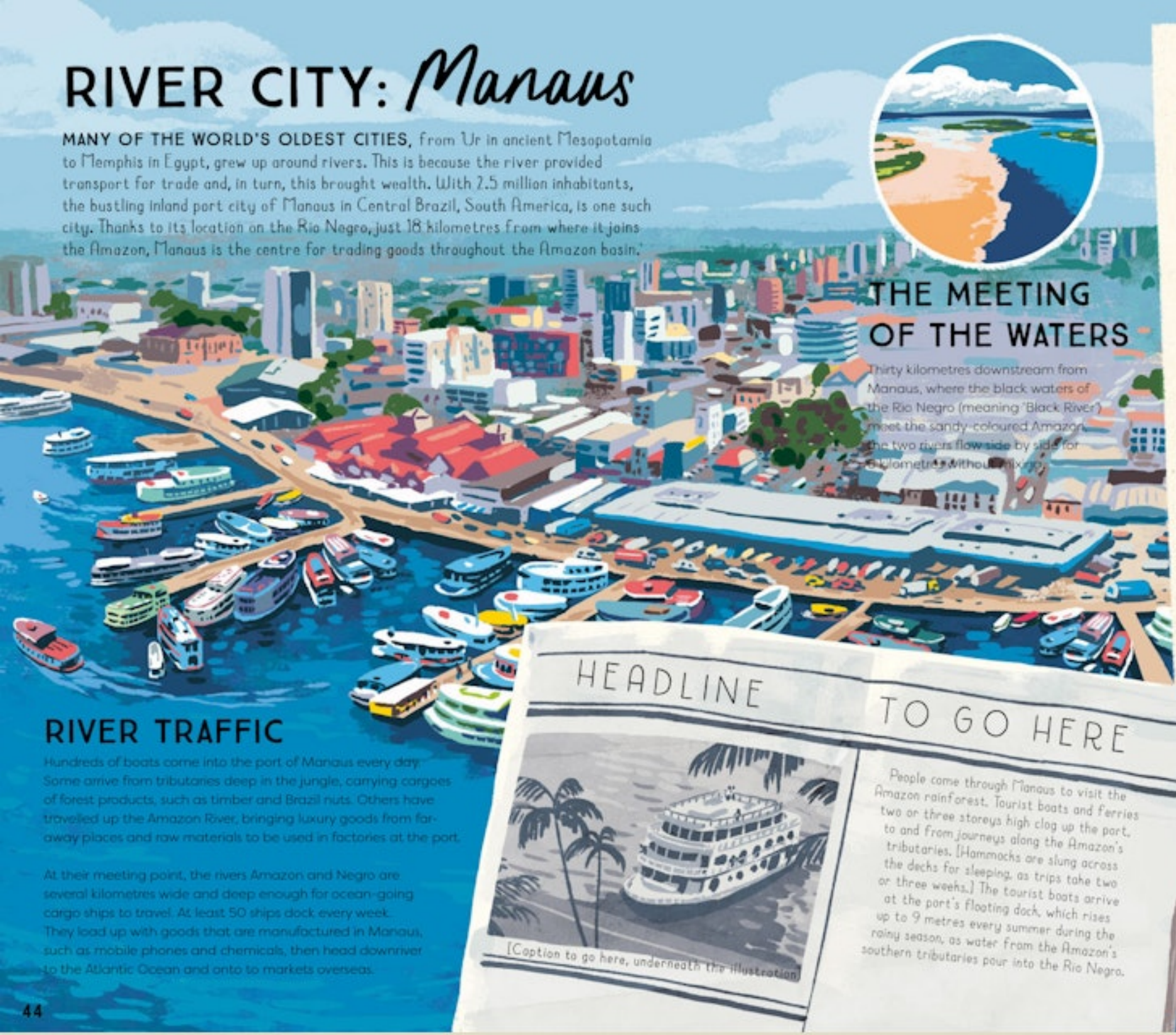


3. Most of the river's flow now takes the shortest route, bypassing the meander. Gradually, the river deposits sediments at the start and end of the loop, building up a riverbank. When the loop becomes separated from the main river, the curving oxbow lake is left.

4. The water in an oxbow lake is still, so the sediments it holds fall to its bed, filling the pool with mud. The oxbow becomes swampy and, eventually, dries up completely. Vegetation grows where the lakes once were.

RIVER CITY: *Manaus*

MANY OF THE WORLD'S OLDEST CITIES, from Ur in ancient Mesopotamia to Memphis in Egypt, grew up around rivers. This is because the river provided transport for trade and, in turn, this brought wealth. With 2.5 million inhabitants, the bustling inland port city of Manaus in Central Brazil, South America, is one such city. Thanks to its location on the Rio Negro, just 18 kilometres from where it joins the Amazon, Manaus is the centre for trading goods throughout the Amazon basin.



RIVER TRAFFIC

Hundreds of boats come into the port of Manaus every day. Some arrive from tributaries deep in the jungle, carrying cargoes of forest products, such as timber and Brazil nuts. Others have travelled up the Amazon River, bringing luxury goods from far-away places and raw materials to be used in factories at the port.

At their meeting point, the rivers Amazon and Negro are several kilometres wide and deep enough for ocean-going cargo ships to travel. At least 50 ships dock every week. They load up with goods that are manufactured in Manaus, such as mobile phones and chemicals, then head downriver to the Atlantic Ocean and onto to markets overseas.

THE MEETING OF THE WATERS

Thirty kilometres downstream from Manaus, where the black waters of the Rio Negro (meaning 'Black River') meet the sandy-coloured Amazon, the two rivers flow side by side for 6 kilometres without mixing.

HEADLINE TO GO HERE

[Caption to go here, underneath the illustration]

People come through Manaus to visit the Amazon rainforest. Tourist boats and ferries two or three storeys high clog up the port, to and from journeys along the Amazon's tributaries. (Hammocks are slung across the decks for sleeping, as trips take two or three weeks.) The tourist boats arrive at the port's floating dock, which rises up to 9 metres every summer during the rainy season, as water from the Amazon's southern tributaries pour into the Rio Negro.

THE RUBBER BOOM

The Amazon, South America

FLOWING WEST TO EAST ACROSS NORTHERN SOUTH AMERICA, through the rainforest of Peru and then Brazil, the Amazon is the greatest river in the planet. Its tributaries collect water from the Andes Mountains in the west, the Guyana Highlands to the north and from the Mato Grosso plateau to the south. By the time it reaches the Atlantic Ocean, the River Amazon is carrying one-sixth of all the world's fresh flowing water.


Continent: Australia
Length: 2,508 kilometres
Source: Indi Springs, Australian Alps
Mouth: Southern Ocean southeast of Adelaide
Drainage basin: 1,061,469 square kilometres
8. Ngaut Ngaut
Now a protected conservation area, Aboriginal people have been living by the cliff overhang close to the river here for at least 17,000 years. Ancient carvings of pictures line the cliff.
7. Darling River
The Murray's main tributary, the Darling is slightly shorter (1,472 km) than the Murrumbidgee but it gathers water over a much larger area.
3. Murrumbidgee River
At 1,485 kilometre long, this is the Murray's longest tributary.
5. The Hume Dam was built in 1936 to regulate water flow and produce hydroelectricity, and at 51 metres it is the tallest dam on the Murray-Darling River system. There are 240 dams in total.
4. Canberra,
Australia's capital, is situated close to the Murrumbidgee.
9. Lake Alexandrina
Just before it reaches its mouth the Murray widens into a shallow expanse of water, 30 kilometres long and averaging only 2.8 metres deep. A dam at the northern end of the lake prevents saltwater entering the Murray-Darling River system.
6. Yarawonga, a town in northeast Victoria, is the starting point of the Massive Murray Paddle. Swan Hill is the end point.
START
10. The Coorong is a long, shallow lagoon, flanked by sand dunes. The Murray meets the Southern Ocean through an opening in the dunes.
2. Murray Gorge
There are 70 kilometres of white-water rapids in the river's upper course, which kayakers can paddle.
1. Indi Springs
The Murray's source, Indi Springs is a small stream close to Mount Kosciuszko in the Australian Alps.

FLOODPLAIN:
Floating Islands of the Sudd

IN SOUTH SUDAN IN CENTRAL AFRICA, the White Nile – named for the whitish clay it carries suspended in its water – spreads out and virtually comes to a halt amongst a maze of weed-choked channels and marshes to form one of the largest floodplain wetlands in the world. This is the Sudd. The name means 'barrier' or 'impenetrable'.

The water is covered with floating mats of swamp grasses, water cabbage, papyrus sedge and invasive South American water hyacinth. The plants clog up the river, sometimes joining into islands 30 kilometres long. The vegetation underneath rots while living plants grow on top. In some places, there is so little oxygen dissolved in the water beneath the mats that fish cannot survive. Elsewhere, in the channels and lagoons in-between, the river life is abundant.

Heavy rainfall around the White Nile's headwaters between August and November cause the Sudd to triple in size to an area roughly the size of England and submerging the river's grassland floodplain. One million people live on the Sudd and their culture, traditions and daily lives have developed around the seasonal changes. When the floods are high and food is abundant, Mundari fishermen use nets to catch fish in the channels between the islands. Semi-nomadic Dinka people bring in their herds of long-horned Ankole cattle to graze the flood-tolerant grasses that grow around the river's edges.

By the time the White Nile emerges from the Sudd, it carries just half of the water it had before. The rest has evaporated into the air.

Mundari fishermen build fishing camps in the marshes. They dry out their catch in the sun to preserve it to eat later in the year.

More than a million antelope, white-eared kob and tiang, migrate to the Sudd yearly to graze on the fresh shoots.

A shoe-billed stork catches a lungfish.

The African Jacana's long toes allow it to walk across the floating vegetation.

Along the channels between the islands papyrus grows up to 6 metres tall.

Nile crocodile

Hippos are a danger to the fishermen in their dugout canoes.

The Nile, Africa

THE LONGEST RIVER IN AFRICA, THE NILE IS ACTUALLY TWO RIVERS – the White Nile, whose headwaters are in Central Africa, and the shorter Blue Nile, which provides nearly all of the lower river's water. After its two branches join, the Nile flows northwards through the Sahara Desert to the Mediterranean Sea, carrying the nutrient-rich silt that led to the rise of one of the world's first great civilisations: Ancient Egypt.

THE RISE OF A CIVILISATION

The ancient Egyptians called the river's fertile silt 'The Gift of the Nile' and it was the reason why the civilisation grew along its banks 5,000 years ago. Every year the people could count on the river flooding. Sometimes these floods washed away homes and whole villages, but the flooding brought water to a desert land and left behind nutrient-rich soil where crops grew well. Wheat to make bread was especially important.

Having more than enough food to eat meant that the first Egyptians were able to do more than just survive. Many people farmed the land, others mined for stone and metals, which they transported in their boats along the length of the river, from the Sudd swamps in the south all the way downstream to Mediterranean Sea and beyond. [Gradually Egypt grew in wealth and settlements grew in size.] The rulers of ancient Egypt, the pharaohs, ordered great building projects, including temple cities like Abu Simbel, Memphis and Karnak, and sent out armies to take land from neighbouring kingdoms, to grow their empire.

CALENDAR

The River Nile's floods were so predictable that the Ancient Egyptians planned their year around them. They had three seasons:

Akhet – The time of the Floods came after the Star, Sirius, rose in the night sky in late June. The water level would rise to about 15 metres deep in August and September.

Peret – The growing season. The Egyptians planted their crops in October after the floods had receded. The fields were now well-watered and covered with river silt.

Shemu – The Harvest. The crops were ready between March and May. Not all years were the same. The height and times of the flood might change, farmers diverted some of the Nile's water into channels to irrigate (water) their fields.

ANCIENT EGYPTIAN CROPS

The Ancient Egyptians cultivated over two thousand types of plants. As well as crops to eat, they grew herbs to flavour their food and to make medicines and cosmetics. Other plants were grown to weave into cloth and make the dye to colour it.

Wheat [the staple food], barley, chickpeas, lentils, garlic, lettuces.

Flax – used to make linen cloth.

Papyrus – reeds used to make paper, wicker baskets, thatched roofs for their mud-brick houses.

DAMS ACROSS THE NILE

The Aswan High Dam, completed in 1970, was built to provide modern Egypt with year-round water and to generate electricity. The dam stopped the Nile flooding downstream which made it safer for people living in the lower Nile floodplain but it also stopped the river depositing its nutrient-rich silt on the land. Now the farmers there use fertilisers manufactured using the hydro-electricity generated by the dam to help their crops grow.

More dams are being built along the Blue Nile by countries upstream of Aswan who want to irrigate crops and generate hydro-electricity. When it is working at full capacity, the Renaissance Dam in Ethiopia will generate enough electricity for the whole of that country. But that is at a cost to Egypt whose own electricity and food production will decrease. The problem is: there just is not enough water in the Nile for the needs of all the countries that want to use it.

To the ancient Egyptians the yearly floods were thought to be the tears of Isis, the goddess of healing, magic and fertility, mourning the death of her husband Osiris, the god of the underworld.

Hapi was the blue-skinned god of the Nile flood and the fertility it brought. Sometimes Hapi is depicted as a mother hippo.

The ancient temple of Abu Simbel was moved (piece by piece) before the valley behind the dam was flooded to make Lake Nasser.

Continent: North America
Length: 3,766 km
Source: Lake Itasca, Minnesota
Mouth: Gulf of Mexico
Drainage basin: 2,980,000 square kilometres

1. Lake Itasca *in Minnesota is the traditional source of the Mississippi. Some of its waters come from Elk Lake 11 kilometres upstream, so some people say Elk Lake is the true source.*

2. *The 308-kilometre-long* **Ohio and Erie Canal** *links the Mississippi River system with the Great Lakes, near the US–Canada border, and the Atlantic Ocean via the Hudson River.*

3. Lock and Dam No.15
This holy city is one of At 367 metres, this is the longest dam across the river. It is one of 43 dams built across the Mississippi to keep the water level deep enough for cargo boats to travel. Dam No.15 and the other dams have locks so that the boats can travel around them.

4. *The* **Missouri River** *rises in the Rocky Mountains. Flowing for 3,767 kilometres, it is the longest river in the USA.*

5. St Louis *is a major trading city where roads, railway lines and the rivers meet. This is where the Missouri joins the Mississippi.*

6. Ohio River
After the 1800s, this linked the more industrialised Eastern states with the states west of Mississippi, the famous 'Wild West' of the late nineteenth century.

7. Memphis
The largest city on the Mississippi with a population of over 630,000.

8. Arkansas River
This major tributary flows from the Rocky Mountains in Colorado state.

9. Atchafalaya Basin
The largest remaining area (5,700 square kilometres) of Mississippi swamp forests and bayous.

10. New Orleans
This city lies close to the mouth of the Mississippi and is known for its good food, music and festivals.

11. Mississippi River Delta
A wetland of winding creeks, sandbars and seagrass meadows, this area is now threatened by global warming (see page xxx).

Mangroves

NEAR THE COAST ON THE VAST MAHAKAM RIVER DELTA IN BORNEO, ASIA, one of the most resilient and adaptable plants on earth lines the riverbanks. Mangroves thrive along tropical and subtropical coasts where few other plants can grow. They survive daily flooding with saltwater and, on the outside edge of the delta, being battered by ocean waves. How? Because of their extraordinary roots.

It is the mangroves' cage-like 'stilt' roots that hold the river mud together. They anchor the plants and in doing this they bind the sediments washed down from the river, stopping land being washed away. The submerged root tangles also provide a protective 'nursery' for shoals of young fish and is a home to crustaceans like prawns and crabs. As the mangroves grow out towards the sea, they increase the length of the river whose banks they hold together, sometimes by as much as 50 metres every year.

Mangroves are designed to survive against the odds. Most plants cannot survive in even slightly salty water, but mangroves are adapted to get rid of the salt that would otherwise poison them. Many species excrete salt through their leaves but the mangroves closest to the sea do this through their roots, which grow outwards under the mud then stick up into the air to do this. Unusually, mangrove seeds sprout while they're still on the tree/branches, ready to start growing as soon as they drop into the mud.

Mudskipper fish climb up the stilt roots with their stiff front fins.

Proboscis monkeys will leap across the channel to avoid salt-water crocodiles.

Like mangroves, nipa palms grow along some of the delta's brackish channels but they cannot survive in the sea's salt water.

Sucker Barb

Amongst the roots the current is slower and, there, young fish are out of reach of most predators.

Salt-water crocodile

Tiger Prawn

Catfish

Kissing Gourami

Fiddler crabs pick off dead plant and animal matter from the mud.

Stilt roots bind the mud together.

[Since XXXX] Thirty eight percent of the world's mangrove forests have been cut down to clear space for shrimp farms. The Mahakam delta has been badly affected. Mangroves are also damaged by water pollution and global warming, which has a knock-on effect to the ecosystem they support. Without nursery areas for marine wildlife, there are fewer fish in the sea. Without mangrove roots holding the mud together and creating a barrier from the ocean, tropical river mouths and coastlines suffer more damage from storms, putting over a billion people's lives at risk.

HEADING UPSTREAM:
The Salmon Run

IN OCTOBER AT THE ADAM'S RIVER IN BRITISH COLOMBIA, CANADA, Sockeye salmon are fighting their way upriver against the current to get to the watercourse where they were born. Three years ago, they migrated downstream to the Pacific Ocean, where they have lived as ocean fish until their bodies were ready for this strenuous return journey. Now the race is on.

Thirty-four million sockeye salmon in the Adam's River and hundreds of millions more in rivers around the North Pacific, from Hokkaido in Japan to Eastern Siberia around to Alaska and Oregon in the USA, are all travelling back home to breed.

Geese fly in V-shape skeins as they flee southwards where the conditions are more favourable.

If there aren't human-built dams in the way, the salmon easily make it through the weak current of the river's lower and middle courses. But near its headwaters, there are rapids to fight through and waterfalls to jump up. Salmon can leap higher than 3.5 metres but, at some falls, predators are waiting for them. Grizzly bears wait to swipe them out of the air with their claws.

By the time they reach the stream of their birth, the salmons' bodies have changed. Both sexes have turned bright pinkish red. The males have developed humped backs and the top half of their mouths have hooked over so that their teeth are on show. This is not for eating. They have not eaten for the full four weeks of their journey. They have changed so that they can fight other males for females to mate with. Once they have mated and the females have laid the eggs, both the males and females die.

The salmon know the river where they were born from its taste. They can detect tiny amounts of minerals dissolved from the sediments the water carries. As the salmon continue upstream and the river splits into smaller and smaller tributaries, they will almost always pick the right stream to follow.

But the eggs survive and there are thousands of them. In one to three years' time, the young fish that hatch will work their way downriver to the Pacific Ocean and the cycle will start again.