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Educational, Scientific and
Cultural Organization



Mission to Mars, p. 2

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We walked on the Moon

On 20 July, it will be 40 years since human beings walked on the Moon. Incredibly, this exploit may well be surpassed this century: NASA is making tentative plans to establish an international base on Mars within the next 30 years or so. This means that our children may not only live to see images of people walking on Mars; some of them may even be crew members! It is thus with our younger readers in mind that we have imagined the scenario in this issue for a *Mission to Mars*.

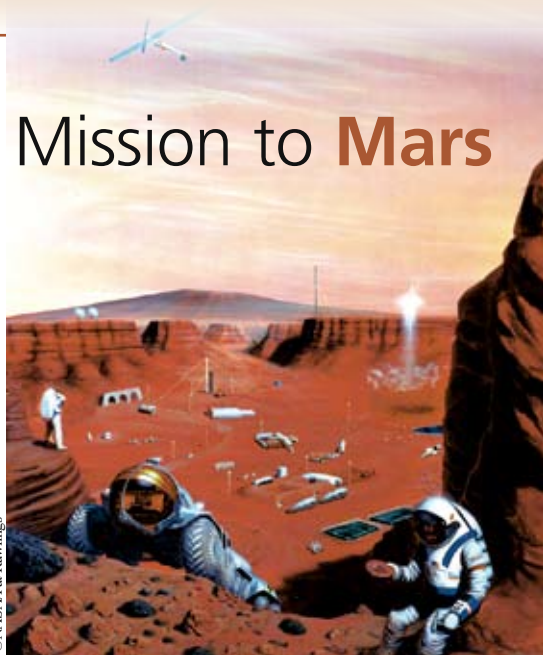
Forty years after we walked on the Moon, another landmark in human endeavour is being celebrated this year. On 24 November 1859, Charles Darwin published *On the Origin of Species*. This work introduced the theory that species evolve over the course of generations through a process of natural selection which favours certain traits over others to give an organism a better chance of surviving long enough to reproduce. Over the past 150 years, evidence accumulated from palaeontology, evolutionary biology, microbial genetics, molecular genetics, embryology, anatomy and other scientific disciplines has systematically corroborated the theory of evolution.

Evidence of evolution has even come from an unexpected quarter: nuclear physics. Claudio Tuniz from UNESCO's Abdus Salam International Centre for Theoretical Physics explains in these pages how new chronometers and x-ray microscopes developed through research in basic physics are helping to trace human evolution and dispersal over the past two million years. Tuniz participated in a series of symposia and exhibitions on basic issues in evolution held in Venice (Italy) from 27 April to 14 May. These events were organized at the Istituto Veneto di Scienze, Lettere ed Arti by UNESCO and the International Union of Biological Sciences, as part of celebrations commemorating the 200th anniversary of Darwin's birth.

It has been said that *On the Origin of Species* dealt one of two stunning blows to humanity's self-image, the other being Nicolaus Copernicus' theory *On the Revolutions of the Celestial Spheres*, which explained that the Sun was the centre of our Solar System and not the Earth. Theological resistance at the time was so strong that Copernicus waited until he was on his deathbed to publish his theory in 1543.

When Neil Armstrong set foot on the Moon, he said, 'This is a small step for a man, a giant leap for mankind.' Copernicus and Darwin could have uttered those very same words as they handed over their manuscripts to the publisher. One small step on their part and humankind took a giant leap forward. Thanks to them, schoolchildren the world over know who they are, where they come from and where they live. 'Scientific thought is the common heritage of humankind,' Nobel Laureate Abdus Salam used to say. Whatever the nationalities of the men and women who set foot on Mars one day, they will owe an awful lot to the pioneers who blazed a trail to the Moon a century earlier.

W. Erdelen
Assistant Director-General for Natural Sciences



©NASA/Pat Rawlings

An artist's impression of a human base on Mars. The astronauts are in the great canyon, Valles Marineris. In the background is Pavonis Mons, a volcano on the equator

Molly wants to know how long it will take us to get to Mars. She has to decide what to pack, after all. When I ask her how far she thinks it is to Mars, Molly says, 'We learned at school that the Earth is 150 million km from the Sun and that Mars is, on average, 228 million km from the Sun.'

'It's not quite that simple,' I caution. 'This does not mean that the Earth and Mars are, at any given moment, 78 million km apart. The Earth and Mars move around the Sun in their orbits at different speeds from one another and their orbits are not the same shape. The shape of the Earth's orbit is closer to a circle than Mars' orbit. The distance between the Earth and Mars varies quite a bit, from 55 million km to 250 million km. Owing to the fact that the planets are moving relative to each other, the trip must be planned so that the trajectory of the spaceship and the orbit of Mars intersect. This opportunity, called a 'launch window,' arises only every 26 months, so when planning to travel to Mars, or the journey home for that matter, timing is essential. Scientists and engineers study *celestial mechanics*,

When I ask nine year-old Molly why she is so intently searching Internet for warm clothing, she states simply, 'I have decided that, when I grow up, I am going to be an animal trainer or a veterinarian – on Mars.' Molly belongs to the first generation of human beings for whom that statement is not necessarily science fiction. 'So I shall need warm boots, very warm boots,' she adds.

Molly recently heard former NASA astronaut Don Thomas say that he was 39 years old when he made his first trip into space. If humans head for Mars in the next 30 years or so, as NASA has suggested, Molly will be just about that age. Nowadays, it makes sense for children all over the world to include Mars in their list of potential career postings. Space agencies from various countries are working together to plan science missions to the Moon, Mars and beyond. Before placing Mars on her list of the *Top 10 Places to Live and Work*, however, I convince Molly that we should spend some time learning a bit more about the Red Planet. We may end up needing more than warm boots.

also called *orbital mechanics*, to decide the best time for a launch. If your brother or sister wants to be this kind of *mechanic*, Molly, they had better pay attention in their mathematics class at school!

Getting to Mars

The trip to Mars could take anything from six to nine months, depending on the orbital configuration and fuel budget for the mission. The cost of flying to Mars is 'astronomical,' so to speak, so the space agencies collaborating on the mission would minimize costs by reducing speed to economize fuel and by waiting for a launch window in both directions. Nine months? That's a long time to travel in space. It only took three days to get to the Moon.



©Susan Hoban

Molly contemplating a model of an unpressurized Mars rover that she built one Saturday morning

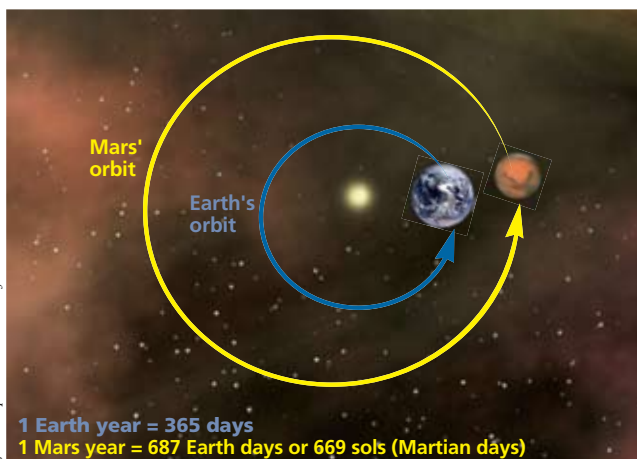


Image adapted from: www.universetoday.com/guide-to-space/mars/distance-from-earth-to-mars/

People have actually sojourned in space for much longer than nine months. The record goes to Valeri Polyakov, who worked aboard the Russian space station *Mir* for 437 days. Just like life aboard *Mir*, during the trip to Mars, the crew would be living in a weightless environment. Everyday activities could become an adventure in a world without gravity. What does it mean to be upside down when there is no gravity to point to where 'down' is?

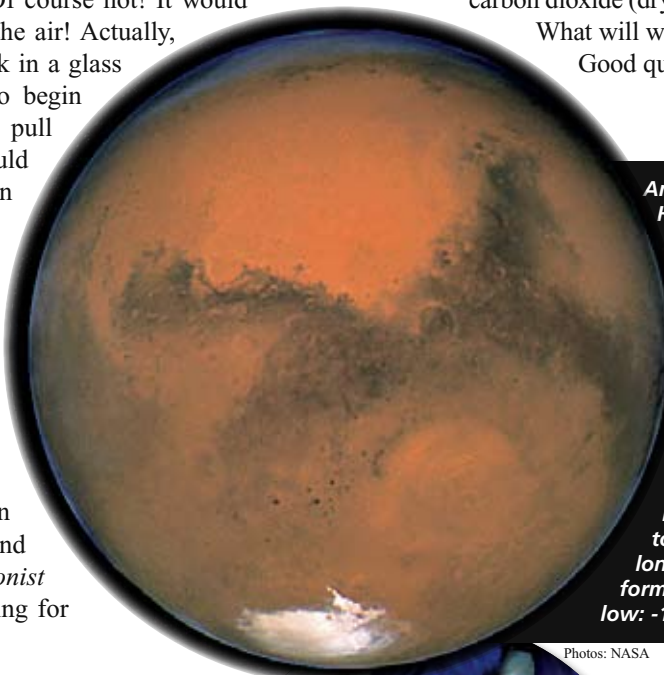
This figure shows Earth and Mars close to each other. However, as they travel around the Sun at different speeds, more often than not, their respective orbits do not bring them close together. The orbits of the planets around the Sun are called ellipses. Eccentricity is a measure of how far from a circle an ellipse varies in shape. A circle is thus an ellipse whose eccentricity equals zero

The human body did not evolve in a weightless environment. Studies show that spending a long time without gravity can waste a person's muscles and bones: humans lose 1–2% of their bone mass every month in space. While lower gravity makes it easier to move around, muscles and bones need to work to stay strong. So during the long trip to Mars, the crew would concentrate on staying in shape by exercising regularly and often. Add *physical trainer* to the crew of the Mars mission.

Of course, weightlessness is not all bad. Just imagine spilling a glass of milk while in a zero-gravity environment. Would it make a mess? Of course not! It would form drops that hung in the air! Actually, you'd never put your drink in a glass or any open container, to begin with. With no gravity to pull it 'down,' the liquid would have no reason to stay in the glass. Onboard the Space Shuttle, drinks are typically stored in a dehydrated fashion and hydrated as needed into a pouch. NASA maintains the Space Food Systems Laboratory at the Johnson Space Center to conduct research on engineering space food and its packaging. Add *nutritionist* to the list of crew preparing for the trip to Mars.

In addition to learning to eat in a low gravity environment and exercising to keep their bodies healthy, crew members would be constantly training for life on Mars during their trip. Mars will be a new and exciting world, very different from Earth. Let's investigate what the physical conditions on Mars are like, so that we have an idea of what would lie in store for Molly and her friends on their journey to Mars.

Female crew member Ellen Baker on an exercise bike on board the space shuttle Columbia. It is important to exercise muscles during space travel to keep them healthy, since they do not work as hard in low gravity



An image of Mars taken on 26 August 2003 by the Hubble Space Telescope. In space, a telescope is not encumbered by city lights. The Hubble image thus shows much more detail and better colour than we would expect to see from the ground. The frozen polar caps of Mars seen here are a mixture of water ice and solid carbon dioxide. Near the Martian south pole, this ice lies just 1 m below the surface. The polar ice caps grow and recede with the seasons, which last twice as long as on Earth because of the greater distance from the Sun. Underground reserves of water may break through the surface as springs but Mars is too cold and its atmosphere too thin to allow liquid water to exist at the surface for long. It is unlikely that this ice could contain a life form based on liquid water, as the temperature is too low: -128°C at night in winter

Photos: NASA

Crew members eating a meal together onboard the space shuttle Columbia. In space, one crew member's ceiling is another crew member's floor!



Finding water on Mars

When I ask Molly what she knows about Mars, the first thing she says is, 'Well, it's red.' Correct, Molly, in fact, it is often called the 'Red Planet.' When I ask her why, she isn't so sure. In fact, the red colour is rust! It is the iron oxides in the soil which give the planet its reddish hue. This reddish hue is one of the first things you would notice on approaching Mars.

On landing, you would quickly suspect that there is no liquid water on Mars. It is too cold. We have known for a long time that the polar ice caps contain frozen water and frozen carbon dioxide (dry ice). 'So there is no water on Mars? What will we drink and bathe with?' Molly asks. Good question.

Last year, the Phoenix spacecraft landed on the Martian surface to study the ice near the north pole and search for organic molecules in the soil. The Phoenix mission found a significant amount of water ice in the soil which appears as frost. So there is water on Mars but it is frozen. Figuring out a way to use it to sustain a human presence is a challenging project for space engineers to work on. Add *hydrogeologist* to the list of jobs on Mars.

In the meantime, scientists have worked out ways to recycle wastewater, a technique which might come in very handy on the mission to Mars. In November 2008, the Water Recovery System devised by MichiganTech in the USA was sent up to the International Space Station in orbit 350 km above the Earth. Astronauts at the space station are accustomed to recycling every last drop of water: evaporated water from the shower, water from



Photo: Wikipedia Commons

In an experiment to test the feasibility of setting up a colony one day on the Moon or Mars, eight volunteers were sealed inside an air-tight complex known as Biosphere 2 from 1991 to 1993. Built in the USA, the complex reproduced various ecosystems, including a desert, savannah, ocean and forest. Although oxygen had to be pumped into the complex periodically and the crops failed to thrive, much was learned from the two-year experiment about how to design space colonies

teeth-brushing, hand-washing and shaving – even their own perspiration!

The new Water Recovery System goes a step further: it recycles urine into drinking water! The urine is first distilled before it joins the other recovered fluids in a water processor to filter solids like hair strands. In the next stage, the wastewater trickles through a series of filtration beds to extract contaminants like microbes. The last step is a reactor which breaks down any remaining contaminants into carbon dioxide, water and a few ions.

Drawing of a rover like Spirit and Opportunity, which have been exploring Mars since 2004

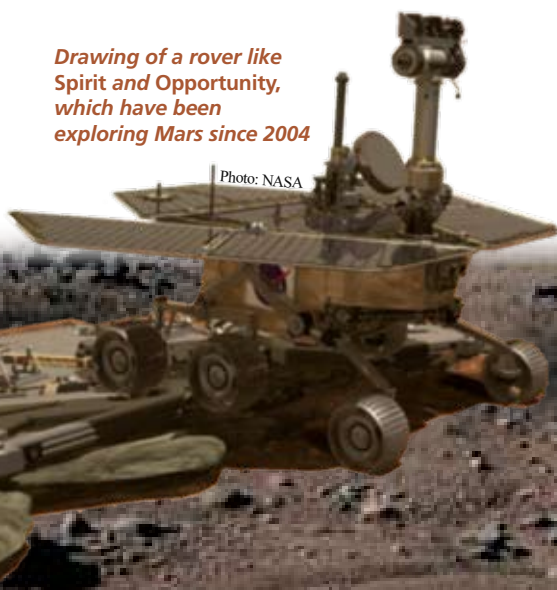


Photo: NASA

Setting up home on Mars

We have known for a long time that it is colder on Mars than on Earth. ‘We didn’t need to send spacecraft to Mars to figure that out,’ quips Molly, ‘since Mars is farther from the Sun than Earth.’ True but how cold? Reported temperatures vary somewhat but it is clear that, at its coldest, Mars is colder than anywhere on Earth, with temperatures plummeting to about -128°C at night in winter.

In order for humans to survive long in such cold temperatures, it will be essential to improve space-suit technology and the heating and insulation of living quarters on Mars. There’s plenty of work for innovative engineers and architects in this area, so add them to the list of essential jobs for the mission to Mars!

Tailoring space suits to life on Mars

The space suit is a complicated habitat of its own. It must adjust pressure and temperature, while providing breathable air. A space suit must provide protection from harmful radiation and micrometeorites, while at the same time being flexible enough to permit easy movement.

Furthermore, the space suits worn by astronauts on the Moon will not be adequate for Mars because the gravity on Mars is greater than on the Moon. As a result, much more attention will be paid to making the space suits light enough so that they do not exhaust the astronaut, yet strong enough to resist the wear and tear in an extremely dusty environment.

See also: www.astronautix.com/craftfam/spasuits.htm

Replica of a NASA space suit



©Susan Hoban

Bluish-white water frost on Martian soil in the northern arctic, photographed last year by the Phoenix Lander

Image: NASA Finding water on Mars

The southern flank of Olympus Mons photographed on a Martian winter morning in 1998 by the Mars Global Surveyor. Olympus Mons is composed of basalt, an igneous rock. It is a shield volcano, meaning that it is shaped like a flattened dome and has been built up by very fluid lava flows



Photo: NASA

Exploring Mars

Once we have set up a home base, the next step will be to explore the Red Planet. To get around, we shall need to use rovers like the one being tested in the Arizona desert (*see photo*).

As a tourist attraction, Mars has a lot to offer. It has the biggest canyon in the Solar System, for instance (*see photo*). It also boasts the Solar System's tallest mountain, *Olympus Mons*, which rises about 27 km high and extends 600 km at its base. *Olympus Mons* is a shield volcano like *Mauna Loa* in Hawaii, the largest volcano on Earth. Both have calderas and have been built up over time by effusive eruptions that produced long lava flows. Some volcanoes on Mars may have experienced explosive eruptions. These would probably have deposited ash on the Martian landscape.

The gigantic size of *Olympus Mons* may be due to the absence of tectonic plates on Mars. As the crust was immobile, the hot spot would not have moved and the volcano would have kept spewing lava in effusive eruptions until it grew to its present size. Martian volcanoes are thought to be extinct today but, if they were once active for a long time, they would have released large quantities of gas which would have warmed the atmosphere and thickened it.

Mars may even have been warm enough for water to flow there,

Humans obviously need food and it won't grow outdoors on Mars, so we shall need to design and maintain an artificial biosphere on Mars that provides food for humans. This said, the Martian soil may contain soluble minerals that plants could use. Scientists came to this conclusion after analysing the Martian soil sample collected by the Phoenix spacecraft last year. One scientist even suggested that asparagus might grow in soil with the same level of alkalinity (or pH) as the Martian sample! Add *agricultural engineer* to the list of Martian careers. It is here that *veterinarian* may also fit into the picture, since humans may desire animals for companionship and possibly for food.

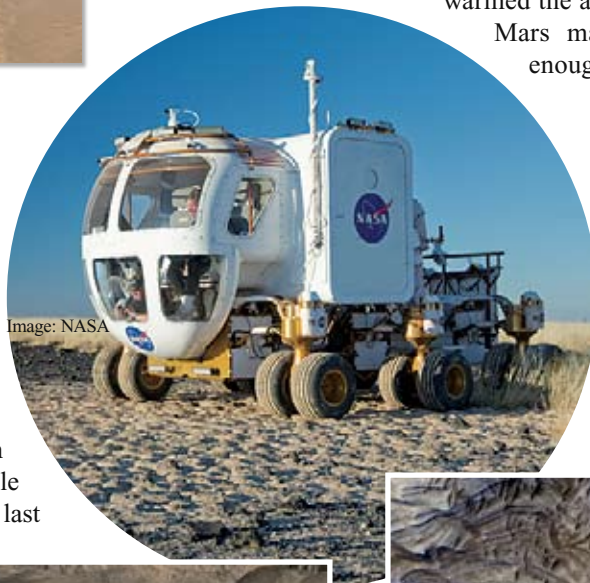


Image: NASA

NASA engineers, geologists and astronauts testing a rover in March 2008 in the Arizona desert, which has a terrain somewhat similar to that of the Moon and Mars. The vehicle is pressurized and could be lived in for several days, giving the astronauts a chance to explore farther afield than in an unpressurized rover



Image: USGS

The Valles Marineris is the biggest system of canyons in the Solar System. It is located just south of the Martian equator. In places, the canyon floor reaches a depth of 10 km. At one time, water may have flowed through the system, which is about 4000 km long



Image: NASA

Tectonic fractures in the Valles Marineris on Mars. Whereas Earth tectonics involve sliding plates, Martian tectonics seem to be vertical, with hot lava pushing upwards through the crust to the surface. The marks in this eroding bedrock suggest that a liquid substance once flowed here. This view is about 1 km across

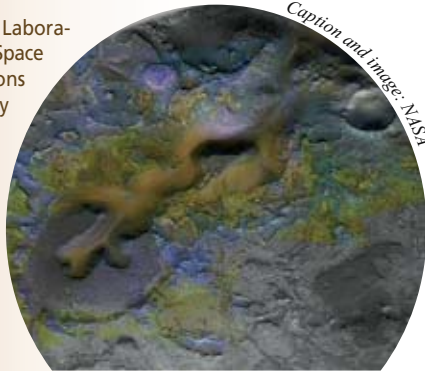
The search for Martians

The idea of there being life on Mars has tantalized Earthlings for a very long time. NASA's Viking 1 and Viking 2 spacecraft journeyed to Mars in 1976 to study the surface and search for evidence of life. These missions determined that the soil was composed of iron-rich clay but their biological experiments detected no evidence of life.

Scientists look for evidence of water on Mars because it is thought that life on Earth originated in the oceans. The combination of temperature and surface pressure simply do not permit liquid water on the surface of Mars.

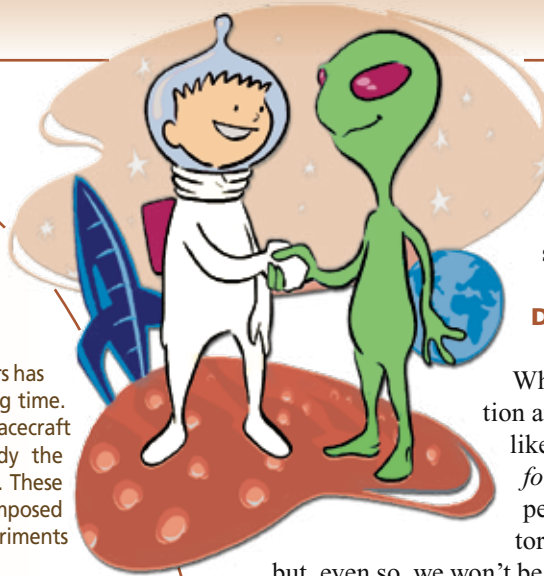
Recently, scientists were able to take measurements of methane (CH₄) in the Martian atmosphere. Methane is what is known as an organic molecule. The term 'organic' here describes the chemistry of carbon chain molecules. Carbon is found in all living things. Methane is the simplest organic molecule, since there is only one link in the carbon chain (and four hydrogen atoms). The recent discoveries of methane on Mars are important to scientists studying the atmosphere on Mars but they do not indicate that life has been discovered there. Methane could also be a sign of geological activity underground.

NASA's Mars Science Laboratory and the European Space Agency's ExoMars missions will be using rovers to study the geology, atmosphere, environment and, once again, search for signs of life on Mars when they are deployed in 2014 and 2016 respectively, the latest launch dates. Looks like we shall need an *exobiologist* on the Mars mission team.



Caption and image: NASA

In December last year, NASA announced that its Mars Reconnaissance Orbiter had found long-sought-after carbonate minerals on the Martian surface, indicating that Mars had neutral to alkaline water when the carbonate minerals formed at these locations more than 3.6 billion years ago. Carbonates (shown here artificially in green in an image about 20 km wide), which on Earth include limestone and chalk, dissolve quickly in acid. Therefore, their survival until today on Mars challenges suggestions that an exclusively acidic environment later dominated the planet. Instead, it indicates that different types of watery environments existed. The greater the variety of wet environments, the greater the chances that one or more of them may have supported life



as suggested by images of what look like dry lake and river beds. We had better add *planetologist* to the list of skills required by the Mars mission.

Dangers to look out for on Mars

What will the weather be like? As the rotation axis of Mars is tilted, it has seasons, much like on Earth (see overleaf *Weather Report for the Solar System*). So there are warmer periods, particularly at the Martian equator. The temperature can reach about 20°C

but, even so, we won't be running around outside on Mars in swim suits, for a number of reasons. Two that immediately spring to mind are our need for breathable air and for protection from harmful solar radiation!

The harsh radiation environment is one of the arguments against there being life currently on the Martian surface. Before humans can set up a sustained presence on Mars, the living quarters, space suits and transportation systems designed for use on Mars will have to provide protection from cosmic radiation.

The composition and density of the Martian atmosphere are quite different from those of Earth. The Earth's atmosphere is composed mainly of nitrogen, which we breathe in and out without using. It is this nitrogen that scatters sunlight around and makes the Earth's sky appear blue to us. On Mars, the sky would appear pink because sunlight is scattered by dust particles, which are larger than nitrogen molecules and tend to scatter red light more than blue light – red light has a longer wavelength than blue light.

Molly interjects at this point, 'We learned in school that carbon dioxide is a greenhouse gas that may be contributing to global warming on Earth. So if the Martian atmosphere is mostly carbon dioxide, why isn't there global warming on Mars?'

This image was taken during NASA's 1997 Pathfinder mission to Mars. The terrain in this northern equatorial region is uneven and rocky. The Twin Peaks hills can be seen in the distance. Last year, NASA's Phoenix spacecraft landed in the northern arctic plains of Mars where the landscape is much smoother with fewer rocks

©Courtesy of Samuel Blanc: www.sblanc.com



View of an aurora over Antarctica on Earth. This beautiful spectacle can be viewed at the poles when the trapped magnetic field of the solar wind collides with the Earth's protective shield, the magnetosphere

Comparing the atmosphere on Mars and Earth

	Earth	Mars
Average surface temperature	15 °C	-55 °C
Surface pressure	1013 mbar (= 1 atmosphere)	6.35 mbar
Composition of the atmosphere	78.07% nitrogen 21.0% oxygen 0.9% argon 0.03% carbon dioxide	95.49% carbon dioxide 2.7% nitrogen 1.6% argon 0.13% oxygen 0.08% carbon monoxide
Atmospheric density* at the surface	1.22 kg/m ³	0.015 kg/m ³

*The atmospheric density on Mars is approximately 80 times lower than on Earth. The atmospheric density of a planet varies, in fact, decreasing with increasing altitude, temperature and humidity. Here, it has been calculated for the average temperature on both planets.

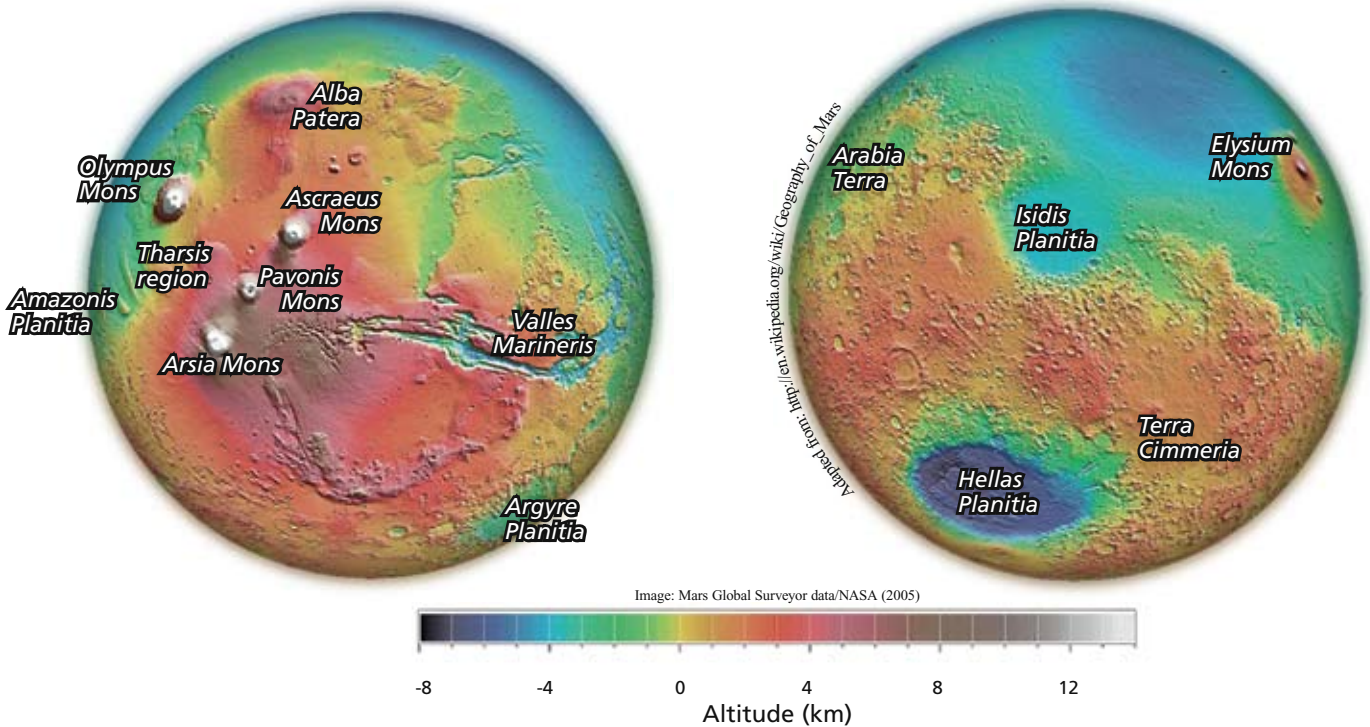
Source: www.esa.int

If you would like to calculate the atmospheric density on Mars yourself, go to:

http://esamultimedia.esa.int/docs/edu/Exercices/Preparing_%20a_%20mission_%20to_%20Mars.pdf

It isn't just the composition of the atmosphere on Mars that is different from Earth. Since Mars is such a small planet, with a mass only one-tenth that of Earth, Martian gravity is too weak to hold on to a big atmosphere. The carbon dioxide in the Martian atmosphere does contribute to warming but only by a few degrees. The amount of carbon dioxide in the atmosphere is even less when some of it freezes and falls to the surface as carbon dioxide snow. So you cannot count on the greenhouse effect to warm up the surface of Mars much.

Not only does the Earth's atmosphere act like a blanket to keep the terrestrial surface warm, unlike the Martian atmosphere; the Earth's atmosphere and magnetic field also act as a shield protecting humans from harmful radiation from space. Potential sources of damaging radiation are the solar wind (charged particles from the Sun), ultraviolet solar radiation (the part of the electromagnetic spectrum that is largely absorbed by ozone in the Earth's atmosphere but is responsible for sunburn) and Galactic Cosmic Rays (high-energy particles that come from beyond the Solar System).



In this map showing the height of landmarks on Mars, we can see that the northern plains have been flattened by lava flows, whereas the south is made up of highlands pitted by ancient impacts of asteroids and comets. The biggest crater on Mars is the Hellas Impact Basin, some 2200 km in diameter, also known as Hellas Planitia – planitia(e) meaning plain. It was once thought that the paler plains of Mars were Martian continents separated by seas, which is why they were given names like Amazonis Planitia and Arabia Terra



Why travel to Mars when Venus is closer? Simply because Venus is a scorching greenhouse world! Mars is the closest thing we have in the Solar System to a twin sister. The temperature on Earth is just right for humans because our planet is an ideal distance from the Sun: any closer and water would evaporate, as on Venus; any farther away and it would freeze, as on Mars.

Throughout the Solar System, the weather is shaped by the same crucial factors: the planet's average distance from the Sun, the tilt of its axis – which causes the seasons – , the shape of its orbit around the Sun, whether or not it has a significant atmosphere and the length of its day. Let's take a little tour to see what the weather has in store for the other planets.

Rain

Ours is not the only planet to experience rain. It suffices for the right conditions to exist for liquid rain to form in the atmosphere, based on the melting point of each chemical. On Venus, it rains sulfuric acid* but this rain never reaches the planet's surface owing to the planet's intense heat. On Saturn's moon Titan, methane rains form lakes and rivers in the northern latitudes. Titan is shrouded in a nitrogen-rich atmosphere which might be similar to that of Earth long ago.

Rain also occurs on the giant gas planets of Jupiter, Saturn, Uranus and Neptune, the atmospheres of which are composed mainly of hydrogen and helium. The additional presence of methane on Uranus and Neptune accounts for their blue hue. Jupiter's clouds are made of ammonia, hydrogen sulfide and water. The planet's fast rotation generates eastward winds of 480 km per hour. Deep in the atmosphere, the pressure and temperature rise, compressing the hydrogen into a liquid. It is thought that Jupiter's Great Red Spot may actually be a hurricane that has been raging for more than 400 years!

Extreme temperatures

Temperature swings on Mercury are the most extreme in the Solar System: up to 430°C during the day and as low as -170°C at night, Mercury having too thin an atmosphere to retain the heat. Its extremely slow rotation results in a long day that leaves plenty of time for the surface to heat up. With the tilt of its axis being zero, there are no seasons.

Venus is covered by thick, rapidly spinning clouds composed primarily of CO₂ (96%) that trap surface heat, creating a scorched greenhouse-like world hot enough (700°C) to melt lead and pressure so intense that standing on Venus would feel like standing at a depth of 900 m in the Earth's oceans.

Jupiter has temperatures of about -148 °C in the highest clouds. However, the temperature varies widely because

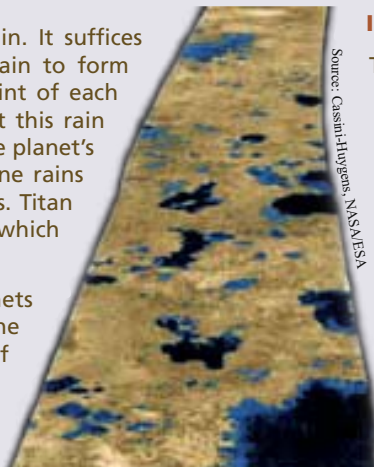
Weather report for the Solar System

of the different chemical compositions that make up Jupiter's atmosphere. As you travel farther into the interior, the temperature rises: at Jupiter's core, it is hotter even than the surface of the Sun!

On Saturn, the temperature oscillates around -178 °C. Saturn's rings are made mostly of water ice.

Near the cloud tops on Uranus, the temperature is -216 °C. The bulk of the planet's mass is contained in an extended liquid core consisting primarily of icy materials: water, methane and ammonia. The planet experiences seasons which last more than 20 years but the temperature differs little on the summer and winter sides because the planet is so far from the Sun.

On Triton, one of Neptune's 13 moons, the surface temperature is as low as -235°C. Despite this, the Voyager 2 spacecraft discovered geysers spewing icy material upward more than 8 km. Triton's thin nitrogen atmosphere is warming for an unknown reason.



Lakes fed by methane rain on Titan

Source: Cassini-Huygens, NASA/ESA

Invisible shields

The magnetic field around a planet acts like an invisible shield, protecting it from high energy solar wind particles from the Sun and elsewhere. Like Earth, Mercury has a magnetic field, or magnetosphere. Mars and Venus do not. The four gas planets all have magnetic fields. Even comets and some satellites, like Jupiter's moon Ganymede, have magnetospheres. Magnetospheres influence a planet's weather and lightning activity.

Jupiter has the most powerful magnetic field in our Solar System, nearly 20 000 times that of Earth's, ahead of Saturn (578 times that of Earth), Uranus (48 times) and Neptune (27 times). Jupiter's powerful magnetic field is generated by an electrical current driven by Jupiter's fast rotation.

The main axis of Neptune's magnetic field is tipped over by about 47° compared with the planet's rotation axis, a misalignment which causes the planet's magnetic field to undergo wild variations during each rotation. Neptune's winds are the strongest in the Solar System: three times stronger than Jupiter's and nine times stronger than Earth's.

Lightning

Anywhere there is an atmosphere, potentially there is lightning, a build-up of an electrostatic charge which generates a flash of light. Lightning has been observed throughout the Solar System. The European Space Agency's Venus Express spacecraft has revealed visible flashes in the atmosphere of Venus's sulfuric acid clouds and localized emissions of radio waves. The vast dust storms on Mars are potential sources of lightning.

Lightning has been directly observed on Jupiter, Saturn and Neptune, and static charges were detected by Voyager 2 as it cruised past Uranus two decades ago. Even Titan has the potential for lightning, although none has been observed yet. One interesting result of lightning may be the formation of biomolecules, the precursors of life.

* Venus has acid rain because the CO₂ in the atmosphere is dissociated into carbon monoxide (CO) and atomic oxygen (O); atomic oxygen reacts with sulfur dioxide (SO₂) to give sulfur trioxide (SO₃), which itself combines with water vapour (H₂O) to form sulfuric acid (H₂SO₄)

KEY

- Diameter of planet
- Length of planet's day
- Length of planet's year
- Planet's (average) distance from Sun

MERCURY
4880 km
1408 hours
0.2 Earth years
58 million km

VENUS
12 100 km
-5832 hours
(Venus rotates backwards)
0.6 Earth years
108 million km

EARTH
12 750 km
24 hours
365 days
150 million km
(= 1 Astronomical Unit, or AU)

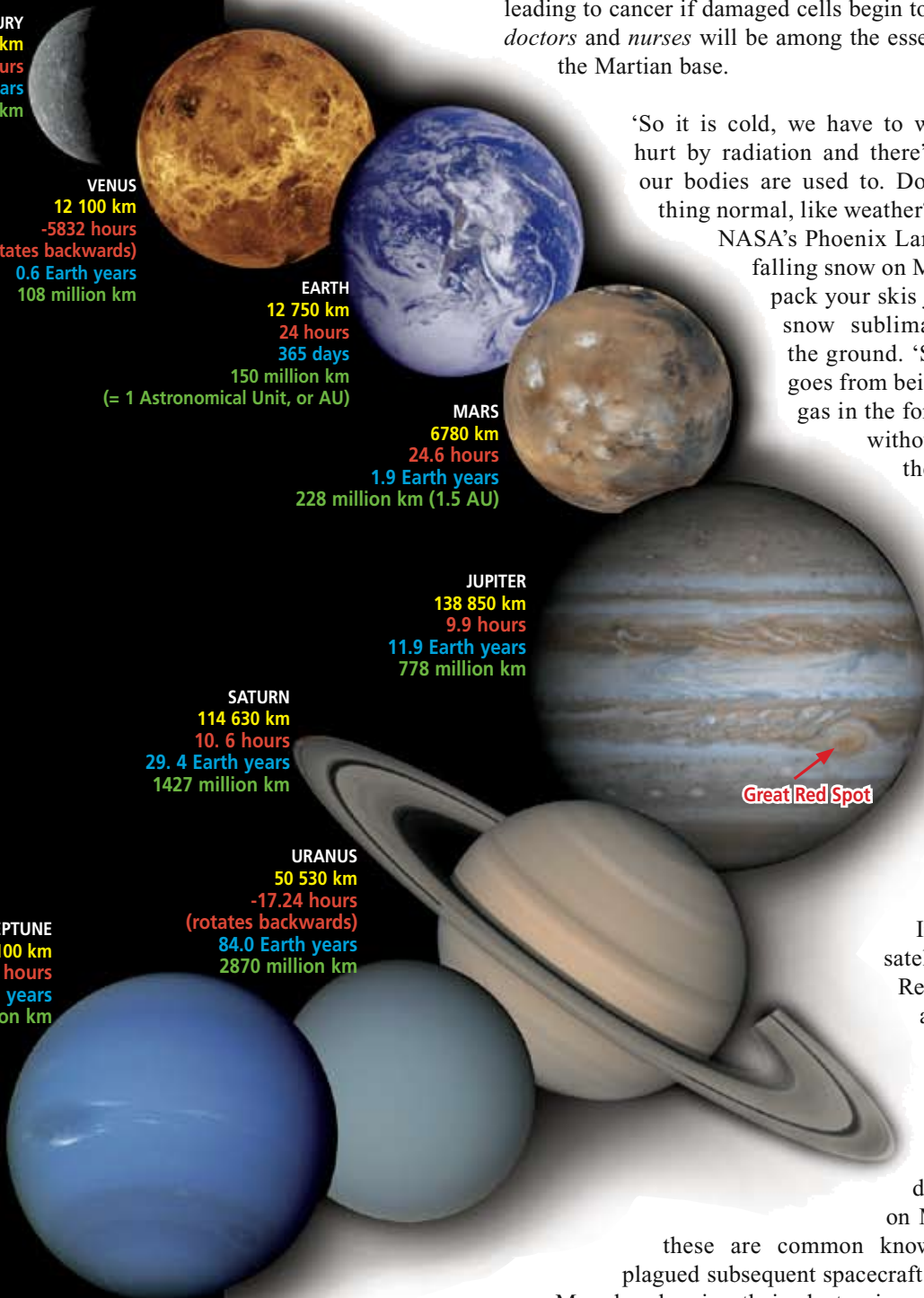
MARS
6780 km
24.6 hours
1.9 Earth years
228 million km (1.5 AU)

JUPITER
138 850 km
9.9 hours
11.9 Earth years
778 million km

SATURN
114 630 km
10.6 hours
29.4 Earth years
1427 million km

URANUS
50 530 km
-17.24 hours
(rotates backwards)
84.0 Earth years
2870 million km

NEPTUNE
49 100 km
16.1 hours
164.8 Earth years
4497 million km



Not reproduced to scale

Text and images of this box adapted from: <http://solarsystem.nasa.gov/educ/themes/index.cfm>

Mars has no magnetic field to deflect the solar wind or Galactic Cosmic Rays away from the planet and the thin Martian atmosphere does not do a good job of stopping the ultraviolet radiation headed for the surface.

Such cosmic radiation will be a great danger to humans because it may damage DNA molecules in living cells, potentially leading to cancer if damaged cells begin to reproduce. Clearly, *doctors* and *nurses* will be among the essential occupations at the Martian base.

‘So it is cold, we have to worry about getting hurt by radiation and there’s less gravity than our bodies are used to. Does Mars have anything normal, like weather?’ Molly asks. Well,

NASA’s Phoenix Lander has discovered falling snow on Mars! But I wouldn’t pack your skis just yet because the snow sublimates before it hits the ground. ‘Sublimates?’ Yes, it goes from being frozen water to a gas in the form of water vapour,

without passing through the liquid phase. If

you want to see an example of

sublimation,

dry ice (carbon dioxide)

sublimates on Earth; it

is often used in food storage to keep

things cold and can be purchased at some

grocery stores.

In 1971, the first satellite to orbit the

Red Planet, Mariner 9,

arrived on Mars during a massive

dust storm that engulfed the entire

planet. Mariner 9

was the first to discover dust storms

on Mars but, nowadays,

these are common knowledge. They have

plagued subsequent spacecraft that have landed on

Mars by clogging their electronics and moving parts, as well as blanketing the solar energy collectors with dust. *Spirit*, one of the two Mars Exploration Rovers that landed on Mars in 2004, suffered a nearly fatal blanketing with fine Martian dust in November 2008.

Would you like to know more?

To read about some of the past, present and future missions to Mars, how to design a space colony, or to find the Martian weather report, follow these links:

on the Viking spacecraft:

<http://nssdc.gsfc.nasa.gov/planetary/viking.html>

on the Phoenix Lander:

<http://phoenix.lpl.arizona.edu/>

on the recent discovery of methane on Mars:

www.nasa.gov/mission_pages/mars/news/marsmethane.html

for a Martian weather report:

www.asc-csa.gc.ca/eng/astronomy/phoenix/weather1.asp

on the Mars Science Laboratory:

<http://marsprogram.jpl.nasa.gov/ms>

on the European ExoMars mission:

www.esa.int/SPECIALS/ExoMars/SEM10VLPQ5F_0.html

on Martian volcanoes :

www.solarviews.com/eng/marsvolc.htm

on designing a space colony:

www.lpi.usra.edu/education/explore/colonies/

see also Mars for Kids: <http://mars.jpl.nasa.gov>



©NASA

This is what the sunset would look like if you were standing on Mars. The Sun appears much smaller than on Earth because of the greater distance. From what you have learned in this article, if the angular size of the Sun on Earth is half a degree (30 arcminutes), what would it be on Mars on average? (See below for the solution)

But dust has not been all bad on Mars. For several years now, we have known about little twisters full of dust on the Martian surface, called ‘dust devils.’ We have them on Earth, too. In March 2005, such a dust devil swept across *Spirit*, cleaning the dust off its solar panels so that it could receive energy again. Although the little dust devil helped the rover, a human probably wouldn’t want to get caught in one, since NASA’s Phoenix Lander recently clocked the wind speed in a dust devil at about 40 km per hour!

Let’s recap. We have talked about the need for food, air, water, shelter and transport. Add the need for a stable power supply to the list of challenges to overcome. Without fossil fuels on Mars, harnessing solar and potentially wind power may be options for the Martian base. However, the solar flux that reaches Mars is, on average, less than half that on Earth and the atmospheric density is much lower, so technologies developed on Earth may not be directly transferable to Mars.

I ask Molly if she still wishes to explore Mars after learning more about it. ‘I think we need to explore space,’ she replies, ‘especially planets other than Earth.’ When I ask her why, a funny look comes over her face and she adds, ‘What if we don’t do such a good job of taking care of this planet?’ That’s a very good question, Molly.

Susan Hoban¹

MARS WEATHER REPORT – SOL 151 **OCT. 27, 2008**

<p>MAX -45 °C</p> <p>MIN -89 °C</p>	<p>Weather conditions deteriorating with a mild dust storm and water ice clouds.</p>		
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Source: NASA/JPL-Caltech/Canadian Space Agency. Wind: University of Aarhus

Purchase a Galileoscope and go stargazing



The Galileoscope™ is a high-quality, low-cost telescope kit developed for the International Year of Astronomy by a team of leading astronomers, optical engineers and science educators. No matter where you live, with this easy-to-assemble, 50-mm diameter, 25–50-power achromatic refractor, you can see the celestial wonders that Galileo Galilei first glimpsed 400 years ago and that still delight stargazers today. These include lunar craters and mountains on Mars, four moons circling Jupiter, the phases of Venus, Saturn’s rings and countless stars invisible to the naked eye. The Galileoscope is a Cornerstone Project of the International Astronomical Union, in collaboration with UNESCO and others.

Each Galileoscope costs US\$15.00 plus shipping costs, or US\$12.50 each for orders of 100 telescopes or more, plus shipping.

To order: <https://www.galileoscope.org/>; for details: info@galileoscope.org (Telephone: +1 603-401-8249); y.berenguer@unesco.org

SOLUTION: *The apparent size of any object varies inversely and linearly with distance. You can prove this yourself using a ruler and a pen: set a cup on a table a known distance away (say, 1 m). Hold out your index finger and mark the apparent size of the cup on your finger. Now, move twice as far away (2 m) and repeat the measurement. How has the apparent size of the cup changed? Using this principle and bearing in mind that 60 arcminutes = 1 degree, we can calculate that the angular size of the Sun seen from Mars = the angular size of the Sun seen from Earth times (the average distance of Earth from the Sun divided by the average distance of Mars from the Sun), or $x = 30$ arcminutes times (1 AU/1.5 AU). Answer: $x = 20$ arcminutes, equivalent to one-third of a degree*

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Disaster risk on the rise, says UN report

Worldwide, disaster risk is increasing for most hazards, says a UN report launched on 8 June at UNESCO headquarters in Paris. Moreover, the risk of economic loss from disasters is augmenting much faster than the risk of mortality.

Disaster risk is concentrated in a very small portion of the Earth's surface and is unevenly distributed,' observes this first edition of the biennial Global Assessment Report on Disaster Risk Reduction, entitled *Risk and Poverty in a Changing Climate: Invest Today for a Safer Tomorrow*. Just a handful of countries – albeit highly populated ones – have been struck by more than one mega-disaster in the past 30 years: Bangladesh, China, India, Indonesia, Japan and the USA.

Although mega-disasters remain rare, half of the 14 costliest and deadliest disasters since 1976 occurred in the past five years. These include the Sichuan earthquake in May 2008, which killed at least 87 566 Chinese and affected more than 60 million. An estimated 5.36 million buildings collapsed and more than 21 million were damaged. The Sichuan earthquake was the 8th most deadly disaster in the past 30 years and the third-most costly – at US\$30 billion – after Hurricane Katrina (USA, 2005) and the Kobe Earthquake (Japan, 1995). Also in May 2008, 133 655 people died after Cyclone Nargis devastated 'the food basket' region of Myanmar.

'In general, poorer countries and those with weak governance are more at risk than wealthier, better-governed countries,' notes the report, which observes that 'small economies are more vulnerable than more diversified ones.' When crops were attacked by locusts in Niger in 2004, the cereal harvest only dropped 11% below the 5-year average and food was available for purchase during the crisis, recalls the report. However, a combination of weak socio-economic and political structures, high market prices and growing poverty –



Forming a human chain to save a man trapped in his car during the worst flood in living memory in Chisinau. In 2005, abundant rain filled the storage lake north of the Moldovan capital, causing the dyke to cede under the pressure. The men were able to help the driver to safety

up from 40% of the population in 1990 to 60% in 2004 – meant that 12 million people needed food aid.

Rural livelihoods are particularly vulnerable in many developing countries. Approximately 75% of those living below the international poverty line of US\$1.25 per day live in rural areas: 268 million in sub-Saharan Africa, 223 million in East Asia and the Pacific, and 394 million in South Asia. 'Even in countries experiencing rapid economic development like China,' says the report, 'there are 175 million rural dwellers below this poverty line.'

The report argues for a radical shift in development practices and a fresh emphasis on resilience and disaster planning. There is encouraging news in this regard. Interim national reports completed by 62 countries on progress in achieving the goals of the Hyogo Framework for Action (2005) show that many countries are making 'very good progress in developing institutional systems, legislation, policy and plans to improve disaster preparedness, and response and early warning.' These countries include the victims of the Indian Ocean tsunami in December 2004, which killed 226 408 people. 'Due to such efforts, many low-income countries have dramatically reduced their mortality risk to hazards such as tropical cyclones and floods,' observes the report.

However, progress has been less encouraging when it comes to addressing other underlying drivers of risk like the lack of access to social protection. The report observes that 'economic growth *per se* does not lead to reduced disaster risk: as economies grow, exposure tends to increase at a faster rate than vulnerability can decrease. Greater social equity can not only reduce vulnerability but also alleviate poverty.'

The report was coordinated by the UN International Strategy for Disaster Reduction, in collaboration with UNDP, the World Bank, UNEP, WMO, UNESCO, the ProVention Consortium and a wide range of other partners.

Read the report: www.preventionweb.net/english/hyogo/gar/report/;
For details: b.rouhban@unesco.org

22 new biosphere reserves

On 26 May, 22 biosphere reserves in 17 countries were approved by the International Coordinating Council of UNESCO's Man and the Biosphere (MAB) programme. A total of 36 sites had originally been proposed by 25 countries. These latest additions bring the World Network of Biosphere Reserves to 553 sites in 107 countries.

From the Jeju Island Biosphere Reserve in the Republic of Korea, the ICC also approved extensions to four existing biosphere reserves: Mata Atlantica (Brazil); La Campana-Penuelas (Chile); North Karelia (Finland); and Dyfi (UK), now renamed Biosffer Dyfi Biosphere.

The island of Jeju also played host to the winners of the Michel Batisse Award for Biosphere Reserve Management. Awarded every two years, the grant of US\$6,000 is shared this year by Boshra Salem (Egypt) for her case study on

Working together for a better livelihood in Omayed Biosphere Reserve and Yuriy Gorshkov (Russian Federation) for his case study on Nature management, conservation, restoration of the biological landscape diversity and socio-economic activity in the Great Volzhsko–Kamsky Biosphere Reserve.

The ICC also acknowledged the 10 winners of this year's MAB Young Scientists Awards, worth up to US\$5000 each: Peggy Prisca Ouoko Yangounza (Central African Republic), Ana Maria Abrazua Vasquez and Paula Irrazabal and Soledad Contreras (Chile), Surima Orto Pozo (Cuba), Yun Son Suk (DPR Korea), Steve Ngama (Gabon), Taher Ghadirian (Iran) Deni Rayn Villalba (Mexico), Marina Rubtsova (Russian Federation) and Khalid Osman Hiwytala (Sudan).

For details and photo gallery: www.unesco.org/en/mab

The new biosphere reserves



© UNESCO/Favio Mayorga

A lagoon in Montebello Biosphere Reserve in Mexico

Great Sandy Australia	Encompasses terrestrial, coastal and marine areas, features world's largest rainforest on sand in the world. Includes Fraser Island, a World Heritage site since 1992. Fosters ecotourism and niche organic agriculture.
Mount Myohyang DPR Korea	According to legend, this sacred site was the home of King Tangun, forefather of the Korean people. It rises nearly 2000 masl, home to 30 endemic plant species, 16 globally endangered plant species and 12 endangered animal species.
Bliesgau Germany	Links two contrasting landscapes: densely populated and urbanized in the north and rural in the south. Extensive ongoing research on ecological changes in the context of global climate change.
Swabian Alb Germany	Population of 150 000. Fosters cottage industries, green businesses, organic agriculture, renewable energy use, etc. Includes Münsingen Military Training Area: closed to the public for 110 years until 2005, it is one of the largest noise-free areas in Baden-Württemberg.
Nokrek India	Biological hotspot in Meghalaya State. Besides harbouring elephants, tigers, leopards and hollock gibbons, is noted for its wild varieties of citrus fruit.
Pachmarhi India	In central Madhya Pradesh State, includes tiger and other wildlife reserves. At interface of tropical, moist, dry and sub-tropical hill forests, a botanist's paradise. Local tribes contribute to forest conservation.
Similipal India	Tiger reserve in eastern Orissa State. This tropical environment also abounds with elephants, panthers, deer and numerous plant species. Local tribes depend on agriculture, hunting and forest products but additional sources of income are badly needed.
Giam Siak Kecil – Bukit Batu Indonesia	Peatland area in Sumatra featuring sustainable timber production and two wildlife reserves, home to the Sumatran tiger, elephant, tapir and sun bear. Research includes monitoring of flagship species and in-depth study of peatland ecology. Interesting experimental area for carbon trading mechanisms.
Jabal Moussa Lebanon	Wild, unspoiled area protected by municipal laws. The valley features rivers and streams, rangeland with landraces, mixed forests with oak, pine and olive groves and many economically important plant species. Home to wolves, hyenas, hyraxes, birds and reptiles.
Tasik Chini Malaysia	Malaysia's first biosphere reserve. Located in the eastern region of Malaysian peninsula. Tasik Chini Lake in the core area is a sanctuary for many endemic freshwater species. Great development potential for handicrafts using local plant species around the lake and its tributary rivers.
Lagunas de Montebello Mexico	High biological diversity. Connects the highland Chiapas and the coastal plain of the Gulf of Mexico. Karst landscape and more than 50 lagoons. Critical for water harvesting and climate regulation. Local communities involved in managing the site, via organic coffee production, reforestation, tourism, etc.
Flores Island Portugal	Azores archipelago. The surface part of a seamount close to the Mid-Atlantic Rift. Created by volcanic activity which started less than 10 million years ago. Includes emerged area of Flores Island and adjacent marine areas. Traditional fishing and eco-tourism (diving, whale and dolphin watching, etc).
Geres/Xures straddling Portugal and Spain	Transboundary biosphere reserve with a joint management plan. Rich forest and peatland ecosystems with numerous endemic species which developed under both oceanic and Mediterranean climatic influences.
Shinan Dadohae Republic of Korea	Land archipelago in southwest. Includes terrestrial and marine areas as well as large tidal flats which serve as resting places for rare migratory birds. Traditional forms of fishing (e.g. hand-fishing) and salt production still practiced.
Altaiisky Russian Federation	In Northeastern and Eastern Altai along major mountain ranges. Covers 3. 5 million ha, 15 000 inhabitants. Includes natural World Heritage site of Altaï in core area. Important for tourism. A reserve since 1932, among the areas of the world least affected by human intervention. Indigenous populations.
Vhembe South Africa	Includes northern part of Kruger National Park, Makuleke Wetlands Ramsar Site, Soutpansberg and Blouberg biodiversity hot spots, Mapungube cultural landscape world Heritage site and Makgabeng Plateau with more than 1000 rock art sites. Agriculture, cattle- and game-farming, hunting. Indigenous populations.
Fuerteventura Spain	Second-biggest island of Canaries archipelago. Includes desert or semi-desert areas, coastal and marine habitats. Rich marine biodiversity (dolphins and cachalots, turtles, etc). One of world's major geopalaeontological observatories. Development of ecotourism and wind-based and solar energy production major focus.
Lajat Syria	On southern border with Jordan. Rich biodiversity, existing rotation grazing schemes, landscape restoration and excavations. Potential for development of Lajat archaeological ruins and education for sustainable development.
Desnianskyi Ukraine	In Eastern Polesie. Forests, rivers, lakes, flood plains and bogs covering 58 000 ha, rare species such as bears and lynx. Organic agriculture and ecotourism on Desna river, Desnianski Zori ecological camp for children. Transboundary ecotourism being developed with Russia. Efforts to establish transboundary biosphere reserve.
Delta del Orinoco Venezuela	Home to more than 2000 plant species and a wide array of land and water fauna. Opportunities to strengthen the indigenous Warao communities, secure their settlements and improve their standard of living.
Cu Lao Cham – Hoi An Viet Nam	Coastal/island/marine site in centre of country, known for its marine species: corals, molluscs, crustaceans and seaweed. Includes Hoi An, cultural World Heritage site, ancient trading port with Europe. Well- positioned for promoting ecotourism.
Mui Ca Mau Viet Nam	On southern tip of country. Boundary between mangrove and Melaleuca forests, reproduction and breeding area of marine species. Plans for ecotourism and cultural tourism, as well as training to improve agriculture and fishing.

Cape Verde joins virtual campus network

The African Virtual Campus for Science and Technology gained a new partner on 16–18 March when staff from the University of Cape Verde attended a sub-regional training workshop for teachers in Dakar (Senegal). This latest addition brings the number of participating countries to four: Benin, Cape Verde, Côte d'Ivoire and Senegal.

Technical and teaching staff from institutions belonging to the network were in Dakar in March to begin producing online courses for students using Cyber Teacher Technology. Also on the workshop programme was how to use communication tools among participating centres and how to use and enrich the virtual regional libraries. Participants also discovered the regional portal of the African Virtual Campus, hosted in French by the University Cheikh Anta Diop of Dakar in Senegal.

As well as participating in the international network, Cape Verde is planning to create its own national network by linking up 10 centres across the archipelago. The project is spearheaded by António Correia e Silva, Rector of the University of Cape Verde, with the backing of Vera Duarte Lobo de Pina, Minister of Education, and Gloria Rendall Ribeiro, Permanent Secretary of the National Commission for UNESCO. Petra Lantz is the project's focal point at the United Nations' office in Cape Verde.

Cape Verde being a One UN pilot country, the project will bring together several partners under the One UN Programme. At the government's behest, the African Virtual Campus will be used to improve the quality and training of teachers at all levels of the education system.

Cape Verde has a population of 519 000, with GNP per capita of PPP US\$2,590 per year. At 72 years, life expectancy is one of the highest in Africa. The country also has one of the continent's best track records for education. Some 99% of children attend primary school and 97% of those aged 15–24 years are literate. There is a good ratio of 1 teacher to 25 pupils and nearly two-thirds (62%) of secondary teachers have formal training. About 1% of the population is enrolled in tertiary education and slightly over half of university students and their professors are women [UNESCO (2009) *Education for All Monitoring Report*].

The African Virtual Campus was launched in July 2008 when Benin became the first host country for the network. It is one of three UNESCO flagship projects contributing to implementation of *Africa's Science and Technology Consolidated Plan of Action*. The other two are Capacity-building in Science, Technology and Innovation Policy and Enhancing Science and Technology Education.

The African Virtual Campus is managed at UNESCO headquarters by Mohamed Miloudi from the Division of Science

Policy for Sustainable Development and in West Africa by Ann-Thérèse Ndong-Jatta, Director of UNESCO's Regional Bureau for Education in Africa, located in Dakar. The project also benefits from financial support from the Spanish Agency for Cooperation for International Development (AECID).

Joining the network before the end of the year will be institutions in Nigeria, Gambia and Togo.

For details: Cristina.Ferreira@unicv.edu.cv;

or gloria.ribeiro@govcv.gov.cv; portal: <http://cva.ucad.sn/> (French only)



A video still of Prof. Tako from the virtual campus in Côte d'Ivoire giving an online lecture in medicine. He is using Cyber Teacher Technology. Each lecture is archived so that students may view it repeatedly if they wish.

A digital library for the world

UNESCO and 32 partner institutions launched the World Digital Library at UNESCO headquarters in Paris on 21 April. The website will provide unrestricted public access, free of charge, to historic manuscripts, maps, rare books, films, sound recordings, prints and photographs, some of them dating back centuries.

The idea of a World Digital Library was first proposed to UNESCO by James Billington from the US Library of Congress. The aim is to expand the volume and variety of cultural content on the Internet, provide resources for educators, scholars and general audiences, and narrow the digital divide within and between countries. The digital library functions in seven languages – Arabic, Chinese, English, French, Portuguese, Russian and Spanish – and includes content in a great many others.

One example of the digital library's treasures is a copy of al-Sufi's most famous work, *Kitab suwar al-kawakib*, published around 964 AD. In this work, al-Sufi (Persia, 903–986 AD) describes the 48 constellations established by Ptolemy and adds criticisms and corrections of his own. Al-Sufi's book spurred further work on astronomy in the Arab and Islamic worlds and exercised a huge influence on the development of science in Europe. This copy is held by the US Library of Congress; it was produced in Asia

in *circa* 1730 and is an exact copy of a lost manuscript prepared for Ulugh Beg of Samarkand in 1417.

Among other treasures are oracle bones and steles contributed by the National Library of China; Arabic scientific manuscripts from the National Library and Archives of Egypt; early photographs of Latin America from the National Library of Brazil; the *Hyakumanto darani* (764) from the National Diet Library of Japan; and the famous 13th century *Devil's Bible* from the National Library of Sweden.

The digital library was developed by a team at the Library of Congress with technical assistance from the Bibliotheca Alexandrina in Egypt. Content and expertise has also come from national libraries and cultural and educational institutions in Brazil, Egypt, China, France, Iraq, Israel, Japan, Mali, Mexico, Morocco, the Netherlands, Qatar, Russian Federation, Saudi Arabia, Serbia, Slovakia, South Africa, Sweden, Uganda, UK and USA.

Visit the library: www.wdl.org/en/

World Atlas of Great Apes now in French

On the island of Jeju on 28 May, UNESCO launched the French edition of the *World Atlas of Great Apes and their Conservation* as a satellite event of the ICC meeting of the MAB programme.

The atlas was originally published in English by UNEP and launched at the first intergovernmental meeting on great apes in September 2005. This 'first' was organized in the capital of the Democratic Republic of Congo (DRC) by the Great Apes Survival Project (GRASP) coordinated by UNEP and UNESCO. The French edition comes in the Year of the Gorilla, a joint initiative by the UNEP Convention on Migratory Species (CMS), GRASP and the World Association of Zoos and Aquariums. It has been published with financial support from the French government.

Three of the four species of gorilla are on the IUCN's Red List as being 'critically endangered'. Particularly threatened are the mountain gorillas of the DRC, Rwanda and Uganda, and the Cross River gorillas of Cameroon and Nigeria, with just 700 and 300 surviving individuals respectively. In the DRC, the population of Eastern plains gorillas has fallen drastically in the past decade to just 5000 individuals, according to some scientists. The most populous sub-species, the Western plains gorilla, found in Angola, Cameroon, the Central African Republic, DRC, Republic of Congo, Equatorial Guinea and Gabon, totals only about 125 000 individuals.



A young lowland gorilla riding piggyback on its mother in the Congo

Hunting poses the greatest threat to gorillas, be it motivated by the search for food – at least a million tons of bushmeat come out of the forests of the Congo basin annually – or by the needs of traditional medicine. Another danger is the destruction of gorillas' habitat by slash and burn agriculture and forestry. The region's abundance in charcoal, gold, zinc, uranium and coltan (used in mobile phones) exacerbates the problem.

The Year of the Gorilla is raising funds for projects in Africa under the CMS Gorilla Agreement adopted in October 2007. The idea is to improve the management of national and border populations of primates and their habitat by ensuring that local people have sufficient means of subsistence, via the introduction of income-generating activities such as ecotourism, sustainable forestry and alternative agricultural practices. One project hopes to spread the use of locally made 'rocket stoves' to thousands of homes in the DRC. These stoves cut charcoal and wood use by up to 70%, create livelihoods for local people and improve air quality in homes. A second project, this time in Cameroon, is proposing the alternative livelihood of beekeeper to reduce commercial bushmeat hunting. A third project is developing mountain gorilla watching in Rwanda where tourism 'now surpasses coffee and tea exports as Rwanda's number one foreign exchange earner', according to the CMS.

UNESCO is supporting the Central Albertine Rift Transboundary Biosphere Initiative, which plans to promote ecotourism to protect gorillas living in the World Heritage sites of the Bwindi Impenetrable Forest (Uganda), Virunga National Park (DRC) and Volcanoes National Park (Rwanda).

UNESCO is also supporting the creation of a transborder reserve between Cabinda (Angola) and the biosphere reserves of Luki in the Democratic Republic of Congo (DRC) and Dimonika (Congo), in order to protect the chimpanzees and ecosystem of the Mayombe tropical rain forest and promote sustainable development. Experts attended a first sub-regional workshop in Kinshasa in April this year, in preparation for the upcoming Tripartite Ministerial Meeting for the countries concerned.

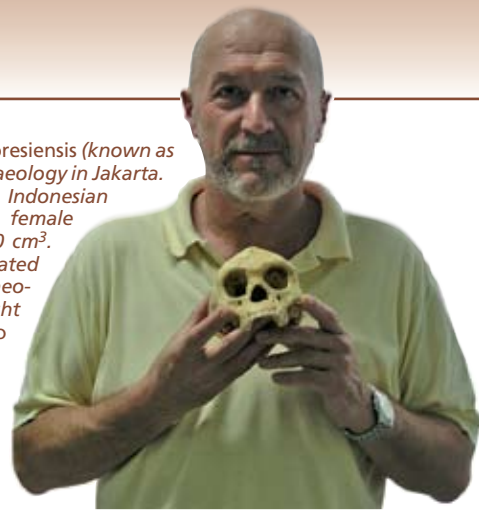
The Year of the Gorilla got off to an auspicious start on 29 January, when rangers from the Institut congolais pour la conservation de la nature published a survey showing that the mountain gorilla population in the Mikeno Sector of Virunga National Park had grown from 72 to 81 individuals since August 2007 when rangers were last able to access the sector. Even so, the rangers noted a worrying level of poaching: four poachers were arrested during the seven-week survey and 536 snares destroyed.

On the Year: www.unesco.org/mab/grasp; mab@unesco.org; www.yog2009.org/

Claudio Tuniz

Out of Africa

Claudio Tuniz holding the skull of *Homo floresiensis* (known as the hobbit) at the National Centre for Archaeology in Jakarta. This skull was discovered in 2003 on the Indonesian island of Flores. It belongs to an adult female about 1 m tall with a brain of about 400 cm³. The radiocarbon age of charcoal associated with the skeleton is 18 000 years. Palaeo-anthropologists suspect the hobbit might belong to a more archaic genus than *Homo*



Evidence is mounting that we all hail from Africa. But when did this migration of anatomically modern humans begin? How long did it take for them to reach all corners of the Earth? And what do we know of our ancestors' way of life and their impact on the environment?

Nuclear physicist Claudio Tuniz has been studying these questions for many years, most recently in his capacity as Assistant Director of UNESCO's Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste. At first glance, the link between physics and human evolution is not obvious. Yet, the tools of modern physics can date human evolution and dispersal accurately. Prof. Tuniz has gone from using particle accelerators to measure the age of meteorites and lunar rocks to using them to pinpoint the age of human bones and teeth.

On 29 April, he was in Venice to describe how the latest developments in physics are being used to study evolution, on the eve of UNESCO's symposium on Darwin, Evolution and Science. Prof. Tuniz is also commemorating 'the Darwin year' with *The Bone Readers*, a book he has just published with co-authors Richard Gillespie and Cheryl Jones; it chronicles the science, political debates and cultural sensitivities surrounding the study of the origin of Australian Aborigines.

Where do we come from?

There are two main theories on the origin of modern humans. The Out of Africa theory puts our species' roots in Africa. The rival multiregional theory states that modern humans evolved simultaneously in various regions. Multiregionalists contend that modern humans in Southeast Asia and Australia evolved from Java Man and that the Chinese descended from Peking Man – both Java Man and Peking Man belong to the species *Homo erectus* – and that Europeans descended from the Neanderthals. However, DNA evidence strongly supports the Out of Africa theory and proponents also claim strong support from bones.

How did human beings disperse?

Population genetics studies suggest that, about 70 000–80 000 years ago, a group of modern humans migrated

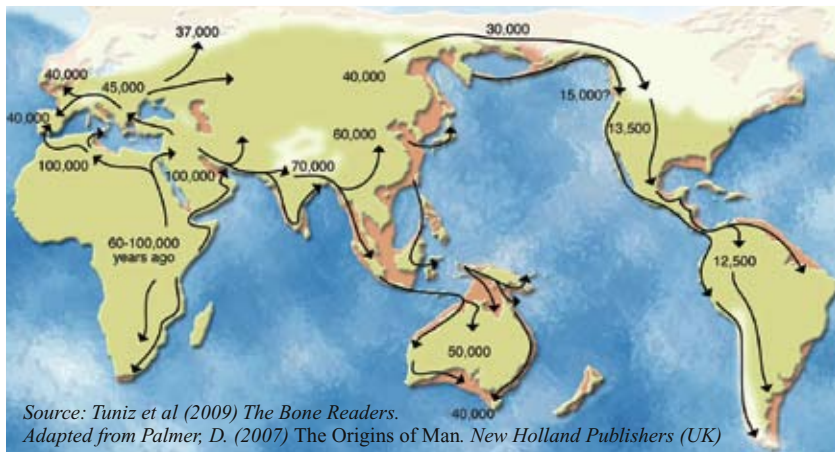
from Africa, where they had evolved from a more archaic *Homo* species about 200 000 years ago. First, they may have spread eastwards, arriving in Asia and in Australia. They reached Europe at least 40 000 years ago and the Americas 14 000 years ago. Along the way, they left behind some clues – bones, teeth, stone tools and remains of human food – that can help us trace their path.

DNA analyses can verify this type of archaeological information. The recent dating of sediments associated with stone tools from India put the artefacts at 77 000 years old. The study of genetic mutations suggests that modern humans travelling from Africa should have arrived in India 60 000–70 000 years ago, so it is unclear whether the artefacts were made by modern humans or by a late archaic hominin population that subsequently became extinct. The same comparisons can be made in Australia and the Americas where DNA analysis supports archaeological evidence that Australia was populated about 50 000 years ago and the Americas 11 000–16 000 years ago. In both cases, the arrival of humans coincides with the demise of the megafauna, the large animals that populated these lands during the ice ages.

What role does physics play in the study of human evolution and dispersal?

In the mid-19th century, Charles Darwin and geologists of his time already had a sense that the Earth and its living creatures had a very ancient origin but they lacked a quantitative method to prove

Dispersal of modern humans according to genetic and archaeological evidence. Coastlines during glacial times are shown in pink



Source: Tuniz et al (2009) *The Bone Readers*. Adapted from Palmer, D. (2007) *The Origins of Man*. New Holland Publishers (UK)

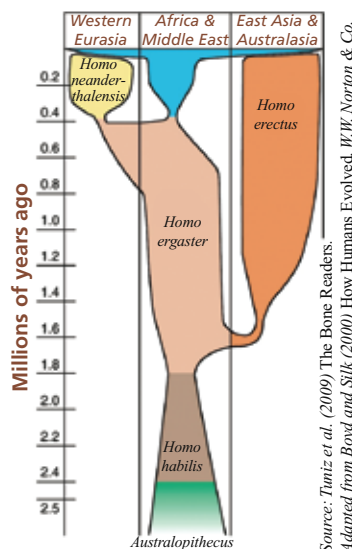
their theory. That became possible only at the end of the 19th century with the discovery of radioactivity. Modern techniques based on radioactivity help us pinpoint precisely the chronology of human dispersal and evolution.

There are several methods, depending on how far back you want to go. The radiocarbon method, based on radionuclide carbon-14 produced in the atmosphere by cosmic rays, can date material to about 50 000 years. Another method known as cosmogenic dating uses long-lived radioactive isotopes of aluminium and beryllium generated when cosmic rays bombard the Earth's surface. It can reach back more than one million years. Still other methods are based on the radioactivity of uranium and on the effects of natural radioactivity on sand grains, known as optically stimulated luminescence dating. There are many others.

Cosmogenic dating was used recently to date Peking Man, a 700 000 year-old archaic Chinese hominin comparable to our African ancestors of the same period. Peking Man's ancestors would have left the African continent in an earlier exodus nearly 2 million years ago. Over this period, the Earth's climate went through several ice ages. During the coldest period of the last ice age 20 000 years ago, layers of ice 1 km-thick covered most of Europe and North America. Sea levels dropped by up to 120 m, opening up new corridors between continents. The 'isotope language', expressed in oxygen and hydrogen isotopes in deep-sea sediments and Antarctic ice cores, speaks volumes about ancient climate.

Scientific tools and procedures developed mainly in physics research can be used to examine ancient hominin teeth and bones and for the non-destructive examination of vases, spears, porcelain and other archaeological finds. These tools include new microscopes based on synchrotron radiation, neutrons and high-energy ion beams that can reveal the structure and composition of cultural artefacts.

In the 1980s, I used synchrotron radiation to study the diet of ancient Normans from Sicily and southern Italy where they established a kingdom in the 11th century AD. I used material from teeth to gain insights into their diet. We are now analysing a tooth from a man found in Visogliano near Trieste, who, according to many palaeoanthropologists, is the common ancestor of the Neanderthal and modern humans. He is a member of the species *Homo heidelbergensis* and is almost



According to this model of human evolution and dispersal, *H. ergaster* evolved in Africa 1.8 million years ago before spreading to Asia where it evolved into *H. erectus*. The blue shading represents *H. sapiens*

Source: Tuniz et al. (2009) The Bone Readers. Adapted from Boyd and Silk (2000) How Humans Evolved. W.W. Norton & Co.

half a million years old. We are also considering the possibility of using cosmogenic dating – the method I employed many years ago to date Antarctic meteorites – to pinpoint his age more precisely.

How could physics be used in future to study human evolution and cultural heritage?

New x-ray techniques enable us to make out minute details in bone and teeth to track evolution. Synchrotron radiation allows us to generate three-dimensional (3D) images of bones and teeth at thousands of times the resolution of ordinary x-ray images without destroying the specimen. We are presently applying this technique to the archaic hominin I mentioned earlier, *Homo heidelbergensis*. The European Synchrotron Radiation Facility (ESRF) in Grenoble (France) is

at the forefront in this field but we have similar projects at the ELETTRA synchrotron facility in Trieste.

In Jordan, the international SESAME centre (for Synchrotron-light for Experimental Science and Applications in the Middle East) set up under the auspices of UNESCO is planning a programme dedicated to archaeology and cultural heritage. This is a topic of paramount importance to the Middle East, where modern humans first met the Neanderthals 100 000 years ago. The region is also rich in cultural heritage from historic times that needs to be preserved and studied. The UNESCO Secretariat and ICTP are actively involved in these programmes.

At the ICTP, we are constructing a portable x-ray spectrometer in collaboration with ELETTRA that will allow us to analyse *in situ*, without collecting samples, the rock art from the Kimberley and Arnhem Land of northern Australia to understand the methods developed by the artists of the Pleistocene.

Claudio Tuniz using synchrotron radiation (bright x-rays) at the ESRF to generate a 3D image of the tooth of an archaic hominin at thousands of times the resolution of ordinary x-ray images. Known as microtomography, this technique promises to unlock the secrets of the developmental biology of Neanderthals, Homo erectus and other hominins. Using the synchrotron, scientists at the ESRF recently discovered that Neanderthal tooth enamel was thinner than that of modern humans, supporting the hypothesis that young Neanderthals grew to adulthood faster than Homo sapiens. Synchrotron radiation is produced by an electron beam accelerated in a ring at almost the speed of light



©Claudio Tuniz

Site in Andhra Pradesh, India. Dated through optically stimulated luminescence by an Australian group, this site contains artefacts made as early as 77 000 years ago. They could have been made by Homo sapiens or by late archaic hominins. The artefacts were found in sediment layers above and below fine ash from the super-eruption of the Toba volcano in Sumatra 74 000 years ago. The eruption was the biggest volcanic explosion in the past two million years; it hurled 2700 km³ of rock and ash into the atmosphere



This tool could also be taken to African museums for use in studies aimed at preserving and understanding materials relevant to human evolution. The analysis could be done locally, without displacing precious, fragile human remains.

Last but not least, we are planning to use cosmogenic dating to confirm the chronology of human remains aged from 500 000 to 1.5 million years. This is a critical period for human evolution and it is important to corroborate other dating techniques that still have large uncertainties.

How did you come to be interested in human evolution?

I have always had an interest in human evolution and archaeology. After spending several years doing pure nuclear physics, I realized that some of the methodology could be applied to many other areas. In the 1980s, I applied x-ray and accelerator methods to studies of cultural heritage and, in the 1990s, I used accelerator-based radiocarbon dating in Australian prehistory. I became very interested in how methods from nuclear physics could be used to study and preserve cultural heritage.

Prehistoric cultural heritage is very important for the cultural identity of indigenous groups like the Aborigines in Australia and native populations in North America.

Tell us about *The Bone Readers*.

In this book, we examine the facts about the first human arrival in Australia, what modern DNA tells us about the origin of Australian Aborigines, theories on the Indonesian ‘hobbits’ and who or what killed off Australia’s giant marsupials. The findings from Australia and its neighbours are echoed in debates over the demise of the Neanderthals and shed light on human evolution. We also discuss how politics and ideology can interfere with the scientific method. There are tensions between science, the management of cultural heritage and the beliefs of the first peoples.

The Australian Aborigines have asked museums and other institutions worldwide to return the bones of their ancestors,

including those that belong to their distant past, with ages up to 40 000 years. As we say in our book, ‘*The controversy has its roots in Australia’s colonial history. Dismissed in the 19th century as primitive and locked in the Stone Age, [the Aborigines] were viewed as interesting specimens by natural historians in the colonies and Europe. The bones of at least 3000 individuals were sent overseas to 70 institutions or more in 21 countries for their collections.*’ Today, when museums return very old human bones to them, Aboriginal communities tend to bury or cremate them, as they consider these bones as belonging to their ancestors.

This creates some tension with the scientific community. In our book, we explain that ‘*many scientists and archaeologists contend that ancient remains are the common heritage of humanity. Research on skeletons could shed light on the life expectancy, health, cultural practices, diet and mobility of past populations. And Australian remains could help settle debates in human evolution.*’

Some Aborigines have also opposed projects based on DNA analysis, like the international Human Genome Diversity Project of the 1990s. It set out to sample the DNA of 100 000 people from between 400 and 500 populations. One of its drawbacks was a plan to preserve some of the DNA material as cell lines. This was abhorrent to some Aborigines. Scientists need to be aware of cultural sensitivities.

Many Aborigines also associate science with the Western world, with the colonisers. When they do, I like to cite ICTP founder Abdus Salam, who used to say that ‘scientific thought is the common heritage of humankind’. Some Aborigines from northern Australia are happy with this idea and would like to be involved in a project where scientific methods are integrated with traditional knowledge. Their oral tradition has been passed on for hundreds of generations, so they say science will only confirm what they already know!

There is still a lot to learn about northern Australia. The Aborigines I have spoken with there would be happy to collaborate with scientists. It is important to decipher, in a non-invasive way, the information carried in cultural artefacts and their connection to the culture of the people who made them. I think there is an important opportunity here for the UNESCO Secretariat and the ICTP could play a role too.

Interview by Mary Ann Williams²

Extracts from The Bone Readers are available at the publisher’s website: www.allenandunwin.com. The book is also published by Left Coast Press (USA) and Springer (Italy).

2. ICTP Public Information Officer: mwilliams@ictp.it

Learning to live with drought in Europe

In recent years, Europe has witnessed successive bouts of severe drought in some areas and torrential flooding in others, leading to fears that climate change is on the move. The idea of a European drought policy has taken hold, in order to ensure the region is better prepared in future, via monitoring, forecasting and information-sharing among countries. In the run-up to the United Nations' conference in December to decide on the successor to the *Kyoto Protocol*, we take a look at the spectre of a growing drought problem in Europe, through the prism of a UNESCO programme on rivers.



Photo : Droeger/Reiss

Shipping was a rare sight at Kaub on the Rhine River in Germany on 3 September 2003. Water levels were so low that this navigation track was only accessible to ships with a light load that did not sit too low in the water. The spur in the middle of the river has been constructed to lift the water table and narrow the river. This helps to increase the speed of river flow, preventing sedimentation from building up in the navigation path. Gravel is used to build spurs, the surface of which is then covered by stones

The need for a drought policy was first brought to the attention of the European Parliament in 2004 by the EurAqua Network of European Freshwater Research Organizations, via a discussion document entitled *Towards a European Drought Policy*. The basic parameters for this policy were developed by a research programme on rivers within UNESCO's International Hydrological Programme that goes by the name of Flow Regimes from International and Experimental Network Data (FRIEND). In 2007, the European Commission posted a document on its website prepared by the water director of each European country in consultation with FRIEND members. Entitled *Addressing the Challenges of Water Scarcity and Drought in Europe*,³ this document is another stepping stone towards a European directive on drought.

Catastrophic summers

In 2003, Europe experienced its warmest summer since records began, resulting in about €12 billion in economic losses (see table). The drop in water levels affected the

stability of dykes, interrupted navigation on the Danube, Elbe and Rhine Rivers and slowed energy production: hydro-electric dams in Spain were operating well below capacity and nuclear power plants in France struggled to find river water to cool their reactors. Crop failure was widespread, forest fires raged and tourists deserted holiday spots in droves, put off by water restrictions, scorched landscapes and record temperatures.

Two years later, the scenario repeated itself, then again the following year and the year after that. Heat waves and drought gripped large areas of central, western and southern Europe, particularly affecting Austria, Belgium, Croatia, France, Germany, Hungary Italy, Luxembourg, the Netherlands, Poland, Portugal, Romania, Spain, Switzerland, Slovakia and the UK. It was then that the European Union realized that drought had become an important feature of the European landscape.

Climate variability or climate change?

One question which torments many specialists is whether the growing frequency and intensity of floods and drought in Europe can be put down to climate variability or climate change. The jury is still out on the question. Monitoring can provide the answer but, if it is to identify trends effectively, it needs to be comprehensive, uninterrupted and long term.

Fortunately, this had occurred to a small team of European scientists back in 1985. They founded FRIEND to make the most of all the information amassed from representative and experimental basins across northern Europe in the 1960s and 1970s. Since then, FRIEND has grown into a global network of eight regional groups with a secretariat hosted by UNESCO. Over 145 countries participate in the programme (see map).

Euro-FRIEND is divided into five groups, each of which covers various research themes. Within one of these themes, researchers are trying to determine to what extent water

Economic cost of drought in Europe, 1992–2008		
Year(s)	Country or territory affected by drought	Economic cost (€ billions)
1992–1995	Spain	> 3.7
1999	In Spain: Andalucia, Aragon, Castillo, Catalonia, Estramadure, Murcia, Valencia	> 3.0
2000	Bulgaria, Czech Republic, Germany, Greece, Hungary, Poland, Romania, Turkey, Western Balkans	> 0.5
2003	Austria, Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Romania, Switzerland, Spain, UK, Western Balkans	> 11.6
2005	France, Portugal, Spain, UK	> 2.0
2006	Southeast UK	> 0.15
2007	Greece, Moldova and the rest of Southeast Europe	> 1.5
2008	Portugal, Spain	0.15

Source : FRIEND

management, human activities and climate drivers all influence drought. As these factors vary from one basin and one country to another, the project is mapping the phenomenon all across Europe, in an attempt to establish a pattern for the hydrological variability of drought and thereby improve drought monitoring, forecasting, prediction⁴ and mitigation.

Why Europe wants to expand fluvial traffic

Euro-FRIEND research into drought is also relevant for the transportation of merchandise on inland waterways like rivers and canals. This form of navigation is more reliable and safer than trucking or rail transport but also particularly sensitive to extremes in river flow. Of course, other sectors such as agriculture, water supply and sanitation services, tourism and electricity are also vulnerable to climate change or climate variability. However, here, we shall be focusing on the particular example of inland waterway transport.

The European Union is keen to expand traffic on the region's inland waterways for a number of reasons. For one thing, this means of transport already plays an important economic role, as it is cost-effective and thus appeals to industry. The total external costs are currently calculated at €10 per 1000 tonne-kilometres, as opposed to €35 for road and €15 for rail transport.

In addition, shifting the balance of transport towards inland waterway navigation would help the European Union reduce its greenhouse gas emissions: emissions of carbon dioxide (CO₂) per tonne-kilometre are lower than for either road or rail transport.

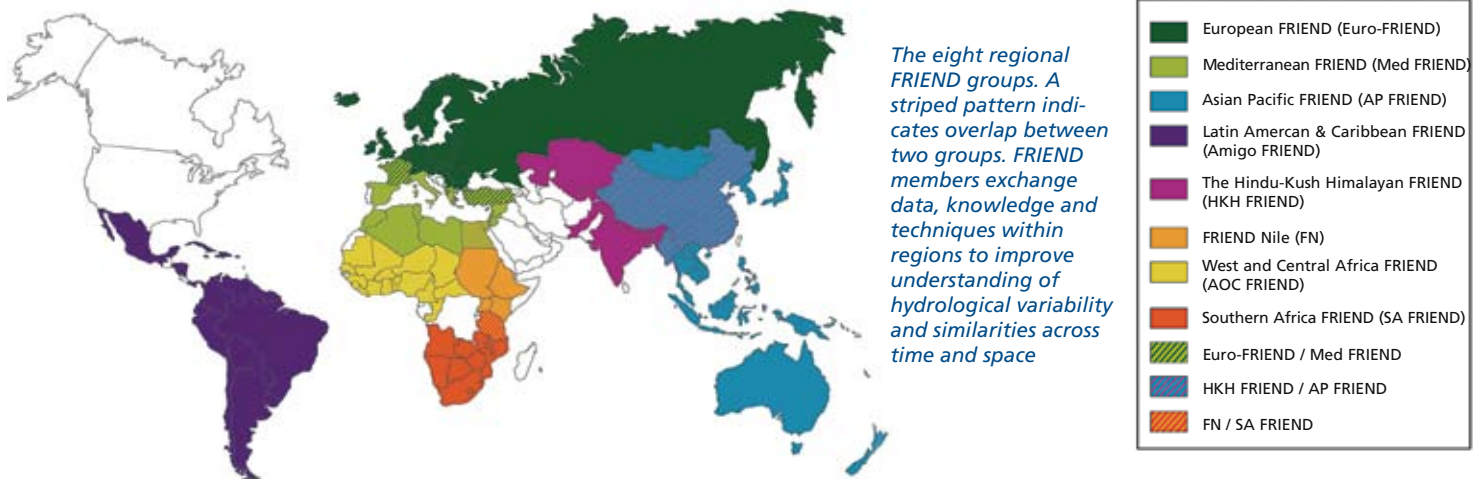
Today, river transport accounts for 6% of total inland transport in the European Union. More than 36 000 km of waterways connect hundreds of cities and industrial regions. Of the 27 member states, 18 have inland waterways and, for 10 of these, interconnected networks of waterways. Fluvial transport plays a vital role in transport through the European northwest but is of little relevance for most of southern Europe where rivers tend not to be navigable.

Have droughts got worse in recent years?

In May 2008, Barcelona in the Spanish region of Catalonia took the unprecedented step of importing a tanker of water from another city on the Mediterranean coast, Marseilles in neighbouring France. After months of inadequate rainfall, the country's reservoirs were down to half their capacity and those in Catalonia were just one-quarter full. The shipment was one of six from Marseilles and ports in Spain, at an estimated cost to the city of €22 million.

Spain is experiencing its worst drought since records began 60 years ago. But is this typical of a wider phenomenon? Europe covers many different climatic zones, with strong variations even within some of the larger countries like France and Germany. Whereas the Mediterranean climate tends to be hot and semi-arid, Central and Eastern Europe have a continental climate that is cooler and more humid.

In 2000, more than 600 daily stream flow records from the European Water Archive were analysed to detect changes in drought patterns across Europe between 1962 and 1990. Conducted by Euro-FRIEND



Getting together among FRIENDs

FRIEND is organizing its sixth global conference from 25 to 29 October 2010 at the Faculté des sciences et techniques in Fez (Morocco), on the theme of Global Change: Facing Risks and Threats to Water Resources.

Authors are invited to submit a paper on one of the four conference topics: hydro-hazards; adaptation strategies; human pressures on limited

water resources; and environmental information and monitoring systems. The deadline for submitting the 300-word abstract in English or French is **30 September 2009**.

Authors will be notified by 31 December 2009 as to whether their abstract has been accepted. The deadline for submitting the full paper is 31 March 2010.

For details and to register (there is a fee): <http://typo38.unesco.org/en/about-ihp/ihp-partners/friend.html>

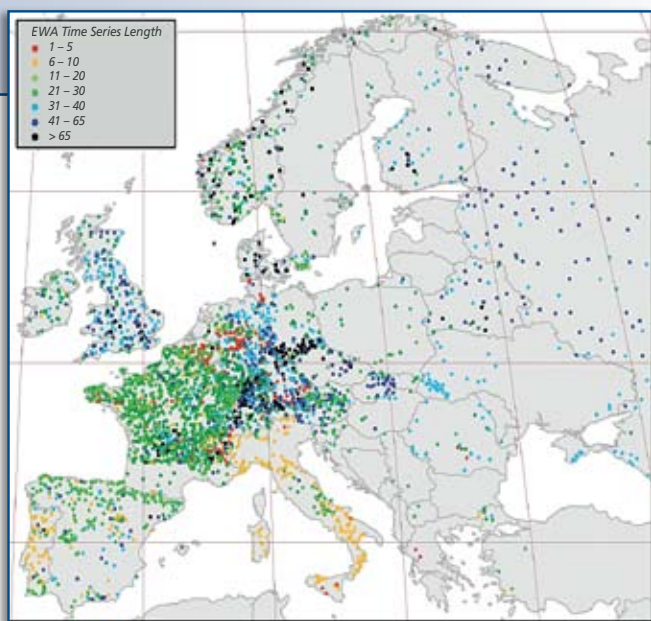
Towards a pan-European system for monitoring and forecasting drought

Scientists have come up with an innovative method for analysing historic pan-European droughts. They measure to what extent the historic average flow of a river has been equalled or exceeded on a given day. For water managers and planners, this is a far more meaningful way of expressing flow than giving simply the total discharge, as it gives an immediate indication of how high or low the flow of a river is compared with the historic record at that site.

Now, a time series of exceedance values across Europe can even be visualized, using commercially available software that can animate and analyse drought development over a given distance.

The exceedance method was first applied in 2000 within the FRIEND project for an Assessment of the Regional Impact of Droughts in Europe (ARIDE). The study selected over 50 gauging stations in 17 countries for the automatic transfer of their data to the pilot system: Albania, Bosnia & Herzegovina, Bulgaria, Croatia, Cyprus, Germany, Italy, Jordan, Malta, Former Yugoslav Republic of Macedonia, Morocco, Norway, Portugal, Slovenia, Tunisia, Turkey and the UK. Countries were chosen for the study according to whether or not their data were available online. For Mediterranean countries, FRIEND used an online data service developed by WMO, the Mediterranean Hydrological Cycle Observing System (Med-HYCOS).

The ARIDE project has shown that it would be technically feasible to set up a pan-European near-real-time drought monitoring and forecasting system based on the concept of flow exceedance and its visualization. For the method to be totally effective, however, countries will need to collect more spatially and temporally representative data. This will mean setting up gauging stations where they are lacking and monitoring them regularly.



The European Water Archive is one of the main outcomes of Euro-FRIEND. This database contains daily flow records from over 4000 gauging stations in 30 European countries, some of which go back more than 60 years, as shown here. It is one of the most comprehensive hydrological archives in the world

within its ARIDE project (see box), the study found no significant change for most stations.

However, distinct regional differences emerged. In Spain, the western part of Eastern Europe and much of the UK, for instance, a trend towards more severe droughts was observed. Large parts of Central Europe and the most eastern flank of Eastern Europe, on the other hand, were found to be experiencing less severe droughts than before.

These trends could largely be put down to regional changes in rain- and snowfall. But there is no clear indication

whether the observed changes are human-induced, part of the natural temporal variation for precipitation or a combination of the two. Also inspiring caution is the fact that the regional patterns observed were strongly influenced by the period and gauging stations chosen for the analysis, as well as by the drought parameters themselves. The work of Euro-FRIEND is thus far from over.

Does a dry winter mean a dry summer will follow?

The UK had experienced seven years of more or less average rainfall before the warm, dry winter of 2004–2005 led to a 40% deficit over much of central and southern England which persisted into the summer. ‘The drought was limited spatially but very protracted and severe in the worst-affected areas’, observed a spokesman from the Centre for Ecology and Hydrology in the UK. After a second dry winter in 2005–2006, the UK Met Office released figures showing that southern parts of England had experienced the driest two consecutive winters in over 80 years.

Scientists deduced from this experience and from their own scenarios for changes in the pattern of high and low atmospheric pressure over the country that winter rainfall had a strong influence on the occurrence of drought in the southeast of the UK.

Were they right? According to a novel study which looked at the links between the storm systems, depressions and other atmospheric forces which sweep across Europe and major droughts on the continent, they were indeed right. The study used data from the European Water Archive covering 1962–1990. Interestingly, the results demonstrated that drought was more likely to occur after a winter which had seen little rain and snow than towards the end of a summer that had been dry.

By combining an electronic atlas with scenarios for changes in the timing and frequency of particular atmospheric circulation patterns, we should be able to model the dynamics of drought from now on and thereby forecast drought. FRIEND brought this prototype system to the attention of Europe’s water managers as long ago as 2001. Alas, they do not yet seem to have developed the reflex to use it.

Siegfried Demuth⁵

On FRIEND:

<http://typo38.unesco.org/en/about-ihp/ihp-partners/friend.html>

One spin-off of Euro-FRIEND is the virtual European Drought Centre established in 2004, an information service currently hosted by Norway: www.geo.uio.no/edu

3. http://ec.europa.eu/environment/water/quantity/scarcity_en.htm

4. Prediction refers to the estimation of future conditions without reference to a particular time, unlike forecasting

5. UNESCO Coordinator of FRIEND: s.demuth@unesco.org

A pinch of salt

Rather than taste seawater to determine its salinity, oceanographers electrocute their samples and measure how easy it is for the electricity to flow through the water. This measurement of conductivity accounts for the electrolytes from dissolved salts but misses other dissolved material in seawater. The conductivity method, or 'Practical Salinity Scale,' has been used by marine scientists since 1978. UNESCO incorporated the scale into the 1980 equations for calculating the density of seawater.

Now, a more accurate way of identifying 'Absolute Salinity' everywhere in the ocean has been devised and incorporated into a Thermodynamic Equation of Seawater. The new equation is set to become the next oceanographic standard as of 2010, after becoming an industrial standard last year. Any company interested in providing drinking water for desert cities near the coast, for example, will use the new method of calculation in building seawater desalination plants. The thermodynamic equation will also make climate models even more accurate than at present. On 24 June, experts attending the 25th assembly of UNESCO's Intergovernmental Oceanographic Commission (IOC) in Paris recommended that the entire oceanographic community adopt the thermodynamic equation and the use of Absolute Salinity.

'I was not familiar with seawater 20 years ago,' says Rainer Feistel of the Leibniz-Institut für Ostseeforschung in Warnemünde (Germany). But the mathematician and physicist had a good handle on energy conservation, thermodynamics and the maths behind complex systems. In the late 1980s, after nearly a decade in Berlin, Feistel moved back home to the Baltic Sea region and started applying his skills to oceanography. The equations he found himself navigating worked fine for the open ocean but developed inconsistencies in regions that were strongly influenced by river drainage, evaporation, precipitation or extremes in temperature. 'As you go to points where there are sensitivities, it's a real mess,' Feistel says. The Baltic Sea was one such region.

'I was surprised,' he says. 'There was a missing mathematical component, a "Gibbs function" which physicists had determined for all sorts of various fluids, except apparently seawater. Named after American mathematician Josiah Willard Gibbs (1839–1903), the 'Gibb's function' defines a fluid in terms of its energy and heat transfer, or thermodynamics.

Water warmer than that above it will rise, just like a hot air balloon rises above the cooler, denser air surrounding it. That is why freshwater from rivers and rain will float on a calm surface and why cold or salty water tends to sink



If oceanographers could distinguish by taste the various salts and minerals in the ocean, seawater would be a great deal easier to analyse. The scientists would sip from their sample jars, swish the water across their palates then spit the water back overboard, licking the residual salt from their lips as they nodded in agreement and exclaimed, 'Ah, yes, a fine example of North Atlantic 35.' Or would they? Perhaps the flavour of dissolved carbon dioxide might linger a moment in their mouths, or the tips of their tongues would find a bit of calcium carbonate chalking the back of their teeth. Such oddities would tell them that the water was not like the usual North Atlantic vintage⁶

What's in a salt?

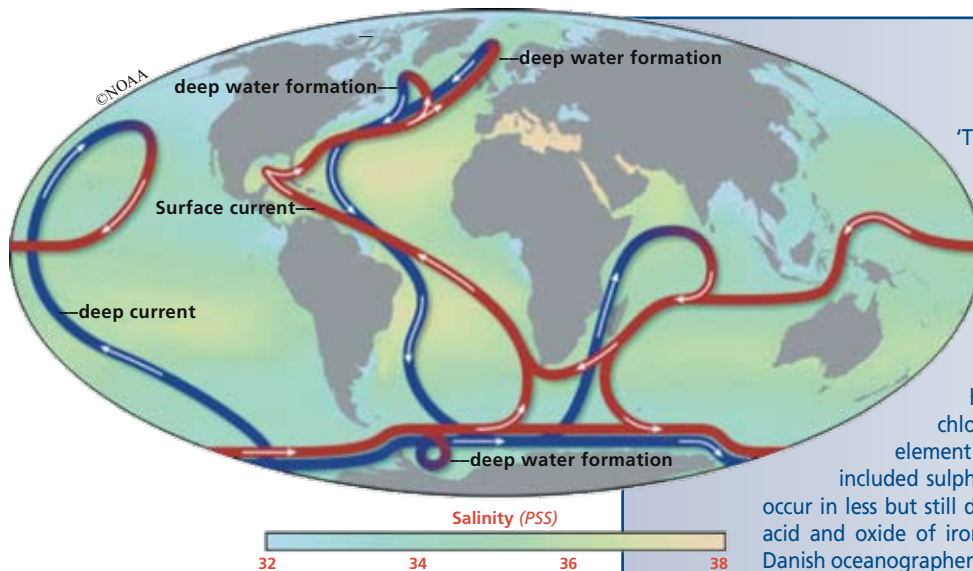
'In chemistry, any positive and negative ion bound together is called a salt,' explains molecular geneticist and chemosensation (taste and smell) expert Hiroaki Matsunami of Duke University in the USA. In the ocean, salts dissolve into free-floating negative and positive ions, also known as electrolytes. These charged particles are what make it possible for electricity to flow through water. The same ions that make up the salt used in foods – sodium (Na^+) and chloride (Cl^-) – account for more than 86% by weight of the 11 major ions in the sea and are what gives the ocean its salty taste. Dried, these ions form table salt and get sprinkled over food.

After chloride and sodium, the ocean's next most common ions are sulfate (SO_4^{2-}) and magnesium (Mg^{2+}). How would the ocean taste if these ions were more common? 'I tasted magnesium sulfate and it tasted really bad but I wouldn't call it bitter,' Matsunami says of the ingredient used in bath salts.

For a century, oceanographers calculated salinity based primarily on measurements of the most common salt ion: chlorine (*see box overleaf*).

The shortfalls of the conductivity method

The conductivity method established in 1978 improved accuracy, as it tracked all the ions in the sea and not



This map measures the equivalent parts of salt per thousand parts of water in the world's oceans, using the Practical Salinity Scale. It also shows the path followed by the ocean conveyor belt, with the warm surface currents in red. The ocean conveyor belt is driven by differences in seawater density

The search for salinity

'The exact chemical composition of seawater is unknown at the present time,' says Frank Millero of the Rosenstiel School of Marine and Atmospheric Science at the University of Miami in Florida (USA). It is not for want of trying. Marine scientists have been searching for the 'magic formula' for measuring salinity for over 150 years.

As early as 1865, Danish marine geochemist Georg Forchhammer found 27 different substances in seawater he sampled from different regions of the ocean. 'Next to chlorine, oxygen and hydrogen, sodium is the most abundant element in seawater,' he wrote. Other major substances he found included sulphuric acid, soda, potash, lime and magnesia. 'Those which occur in less but still determinable quantity are silica, phosphoric acid, carbonic acid and oxide of iron,' he concluded. His tables were used until 1902 when Danish oceanographer Martin Knudsen filtered and distilled North Atlantic water as a seawater standard that all marine scientists could use to calibrate their instruments easily and compare their samples from around the world with a control.

In the 1930s, the introduction of instruments that could measure seawater's electrical conductivity set sailors scrambling to determine whether chemical analysis or the new physical analysis worked better to determine salinity. Conductivity won and by the mid-1950s, deploying a rosette of sampling tubes equipped with conductivity, temperature and depth recorders (CTDs) was becoming a routine part of oceanographic cruises. To maintain consistency, a change to the international standard for seawater was made in 1978 that allowed oceanographers to compare conductivity to a Practical Salinity Scale.

Unlike the Practical Salinity Scale, which accounts only for ions, the new Absolute Salinity will incorporate non-electrolytes using tables that account for how these additional substances vary region by region. Once again, the latitude and longitude at which the seawater samples are taken will play an important role in calculating salinity.

just chloride. But calculating salinity from conductivity, as opposed to old-fashioned chemical analysis, required sacrificing the definition of salinity. This is because conductivity measures only free-floating ions or electrolytes, the same dissolved salts that are found in power drinks. In fact, any non-conductive material, such as dissolved silicon dioxide and carbon dioxide, 'is simply ignored' when it comes to practical salinity, Feistel says.

The Baltic Sea is a prime example of seawater with an unusual composition, far different from the North Atlantic standard. It has electrolytes that conduct electricity but they are not the typical sodium chloride. The vast rivers of Poland and Russia drain into the Baltic Sea, bringing with them dissolved calcium carbonate (CaCO_3) from the limestone river beds. When CaCO_3 dissolves, it dissociates into the conductive ions Ca^{2+} and CO_3^{2-} . These ions prefer to be bound together but, if they can't be, they will often bind to other molecules floating in seawater, changing the mass of the molecules and wreaking havoc with conductivity measurements.

The switch to Absolute Salinity

Feistel's re-evaluation of the 1980s equations provided seawater with a 'Gibbs function'. The previous mathematical equations for determining the properties of seawater had not accounted for water's ability to transfer heat from warmer to cooler currents. Nor did the old equations set a standard for comparing how difficult such a transfer of energy might

be, based on the water's inherent pressure and volume. The thermodynamic equation of seawater chews up all of the old equations and spits out a neat new bundle of computer algorithms that modellers crave.

In 2010 for the first time, the algorithm for measuring salinity will incorporate more than dissolved salt into the conductivity conversion. Millero, who worked on the 1980 equation of seawater, and Feistel are helping to bring about the change. They have been working with modeller Trevor McDougall of the Centre for Australian Weather and Climate Research in Hobart as part of an international team established in 2005 by the Scientific Committee on Oceanic Research and the International Association for the Physical Sciences of the Ocean. They are incorporating the location of the conductivity measurements with chemical analysis from those regions into the new Absolute Salinity calculation. The team has also redefined how the properties of seawater are calculated using this new Absolute Salinity method and combining it with the principles behind thermodynamics to form a single new thermodynamic equation for seawater.

Ensuring any climate model is worth its salt

The fundamental properties of seawater – salinity, temperature and pressure, along with the freezing and

boiling points, heat capacity, speed of sound and density – are intricately tied together. Being able to measure salinity is important, as salinity levels are indicators of climate change. They indicate how much freshwater is evaporating from the oceans. Parts of the Atlantic Ocean appear to be getting saltier, for instance. A possible explanation could be that trapped heat from higher atmospheric concentrations of CO₂ is causing more seawater to evaporate than before, leaving the salt behind.

Secondly, salinity levels affect water density. Density especially determines whether a current rises towards the surface or sinks towards the seafloor, as the denser the seawater, the deeper it will sink. Density depends on temperature, pressure and the amount of dissolved material in the water. Knowing the density of seawater is crucial to monitoring the Earth's climate. The ocean transports heat via currents collectively called the ocean conveyor belt in a process known as thermohaline circulation. In the Arctic and Antarctic Oceans, cool and salty waters sink to form deep water currents. Over thousands of years, these currents travel around the world until they reach areas of upwelling which bring them to the surface. Once at the surface, the sun-warmed, rain-freshened currents head back to the poles where the formation of ice allows the cycle to continue. A massive input of freshwater, such as from melting polar ice caps, can prevent the surface water from sinking and slow down or even stop the ocean conveyor belt, potentially causing great changes to the Earth's climate. 'Every climate model worth its salt depends on our ability to know if hot water goes up and cold water

down, as well as how far and how fast,' observes Keith Alverson, head of the Ocean Observations and Services section of the UNESCO-IOC.

Several factors influence ocean circulation patterns: wind, rain, seafloor topography, the conditions of the surrounding water, as well as the moon and the rotation of the Earth. Ocean circulation models include all of these factors and the computer algorithms that generate the models take weeks to run. Climate change models, which incorporate the ocean's ability to transport heat, take even longer. 'To see what model works best, what fits with the Earth's climate record from the past then run the model forward a century or two can take the best part of a year,' McDougall says. To incorporate non-electrolytes into the equation for salinity then merge the various other equations for different seawater properties into one, McDougall's team has relied on theories from Josiah Gibbs. They are mixing 19th century theory with 21st century computer algorithms.

Based on what they have run so far, McDougall estimates the new equation will show a 3% change in how the ocean circulates heat from the equator to the poles. The other change he is noticing is a 0.5°C difference in the surface temperature of the equatorial Pacific Ocean in both the east and west. Off the coast of Peru, trade winds drive warm surface water away from shore and cold, nutrient-rich, deep water upwells to fill its place. The warm water pools further to the west, warming the air above it and increasing precipitation over Indonesia. During El Niño years, the reduction in the strength of the trade winds allows the warm, nutrient-consumed water to stay closer to the Peruvian shore. The winds push the rain only as far as the central Pacific and Indonesia experiences droughts.

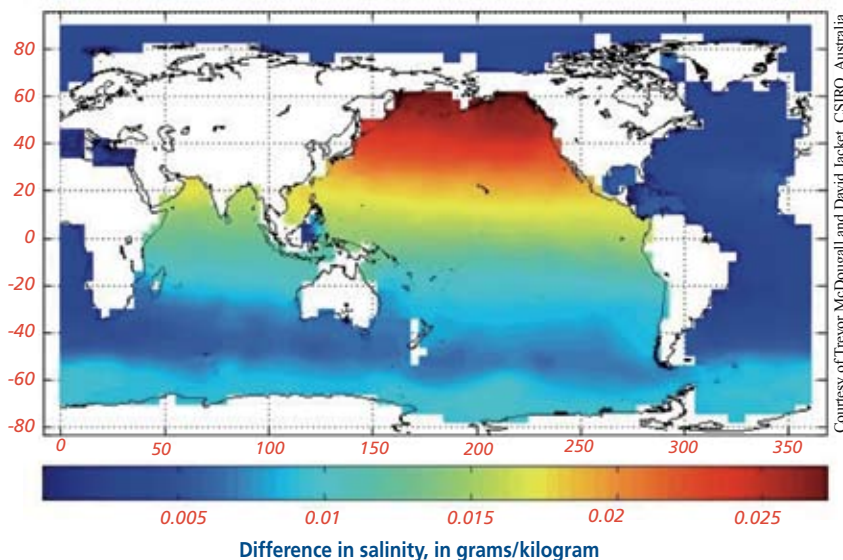
The new thermodynamic equation for seawater allows models to account better for changes in density and for heat transfer as a result of rain falling on the Earth's surface. 'The main reason to do this work is to make these models as accurate as possible,' McDougall concludes.

Christina Reed⁷

For details:

www.ioc-unesco.org/ ; k.alverson@unesco.org

6. Water from the North Atlantic with a salinity of about 35 parts of salt per thousand parts of water has traditionally been used as a control for comparing other water samples. It is composed primarily of sodium chloride
7. Freelance science journalist working with the UNESCO-IOC. Author of Marine Science: Decade by Decade (2009), a history of 20th century oceanography: c.reed@unesco.org



This map shows where the measurement of salinity is most affected by the new Absolute Salinity method (in grams of dissolved material per kilogram of water). Absolute Salinity takes into account all dissolved material and not just salts, unlike the Practical Salinity Scale. The deep red colour is accounted for by additional silicon dioxide in this part of the Pacific Ocean that the Practical Salinity Scale was not picking up. The darkest blue shading indicates little or no change

Diary

23 June – 22 November

Cosmos – journey to the ends of the Universe
Exhibition. Palais de la découverte. Paris.

29 June – 10 July

Invisible Universe

On dark matter and dark energy: exhibition (29 June – 10 July), research colloquium (29 June – 3 July) and colloquium for public (6–10 July). UNESCO Paris: www.unesco.org/iya2009

6–7 July

Reducing earthquake disasters

Workshop of Intl Platform and UNESCO, inviting local authorities to share lessons learned from past and discuss future plans. Istanbul (Turkey). t.imamura@unesco.org

6–13 July

Biosphere reserves in Iberoamerica

Intl seminar. Galápagos Islands (Ecuador): m.clusener-godt@unesco.org

7–8 July

The right to water

Water and legal experts meeting, co-organized by UNESCO's PCCP programme and UNESCO Basque Centre (Etxea), WWAP participating: UNESCO Paris: l.salame@unesco.org; mancisidor@unescoeh.org; www2.ohchr.org/english/issues/water/iexpert/index.htm

12–18 July

General relativity and gravitation

12th Marcel Grossmann Meeting. Scientists to review status of experiments testing Einstein's theory of gravitation. UNESCO Paris: www.icra.it/MG/mg12/en/welcome.htm

17–26 July

Astronomy and world heritage

Intl summer camp for 16–20 year-olds of all nationalities. Vice-Chair of IAU, Fang Cheng, Technical Advisor. Observation of solar eclipse and visit to Suzhou World Heritage site (China). Contact: Ms Cao Fengjiao: whitr_suzhou@yahoo.com

27–29 July

Climate change education

Intl UNESCO/Govt of Denmark seminar to promote integration of climate change education in school curricula in mainly small island states. UNESCO Paris: h.aarup@unesco.org; p.dogse@unesco.org

5–7 August

STI policies in Latin America and the Caribbean: towards a new social contract for science

2nd LAC Forum, to provide input to World Science Forum (November 2009) commemorating 10th anniversary of World Conf. on Science. UNESCO Montevideo, Argentine Min. of STI: Buenos Aires: www.unesco.org.uy; glemarchand@unesco.org.uy

20 August

Sharing an invisible water resource

UNESCO-IHP seminar offering countries practical guidance on how to make use of UN General Assembly Resolution (2008) on Law of Transboundary Aquifers. Stockholm (Sweden): www.worldwaterweek.org

7–11 September

From the Big Bang to civilization

2nd Iberoamerican School of Astrobiology. To put graduate students in contact with scientists from region. UNESCO Montevideo/ Universidad de la República. Montevideo (Uruguay): glemarchand@unesco.org.uy www.astronomia.edu.uy/astrobiologia2009/

14–18 September

European geoparks

8th biennial conf. Open to scientists, non-scientists, tourism industry, land managers, politicians. Global Geopark Naturtejo (Portugal): m.patzak@unesco.org; www.naturtejo.com/contenudos/en/home.php

21–25 September

OceanObs'09

Conf. sponsored by UNESCO-IOC on ocean information for society: sustaining the benefits, realizing the potential. Celebrates a decade of ocean observing system, looks ahead. Venice (Italy): info@oceanobs09.net

Star-gazing nights

17 July – 24 August

Shooting stars

Visible worldwide with naked eye, ideal after 12 August thanks to new moon.

22 July

Longest total eclipse of Sun this century (6 mins 39 secs)

Visible from Bhutan, China, India, Japan, Nepal. UNESCO NatComs in Asia invited to contact UNESCO Jakarta to organize astronomy class for elementary schools: m.nakata@unesco.org

14 August

Jupiter passing close to Earth

Visible all night worldwide with naked eye.

17 August

Neptune passing close to Earth

Visible all night worldwide by telescope.

17 September

Uranus passing close to Earth

Visible all night worldwide by telescope.

6 October

Maximum distance between Mercury and the Sun (18°)

Visible before sunrise worldwide with naked eye.

23–24 October

50 hours of astronomy

IAU organizing public events to observe through telescope what Galileo saw 400 years ago: Jupiter's four moons.

December

Best time to observe Mars

Visible worldwide all month with naked eye.

14 December

Shooting stars

Visible worldwide with naked eye.

31 December

Partial eclipse of the Moon

Visible with naked eye early evening in Africa, Asia and Europe when moon passes in Earth's shadow: 5:15 pm–9:30 pm

For other rendez-vous: www.astronomy2009.org

New Releases

Risk and Poverty in a Changing Climate

Invest Today for a Safer Tomorrow

First biennial Global Assessment Report on Disaster Risk Reduction, ISBN/ISSN: 9789211320282, English only, 207 pp., see p. 11

Biofuels and Environmental Impacts

Scientific Analysis and Implications for Sustainability

UNESCO–SCOPE–UNEP Policy Briefs Series, 9. English only, 6 pp. Summarizes findings of International Biofuels Project launched by Scientific Committee on Problems of the Environment (SCOPE) analysing environmental benefits and problems of commonly used biofuels and their future potential.

Global Open Oceans and Deep-Seabed (GOODS)

Biogeographic Classification

J. Vierrós, I. Cresswell, E. Escobar Briones, J. Rice and J. Ardron (eds). UNESCO-IOC and UNESCO-MAB. UNESCO-IOC Technical Series, 84. English only, 88 pp.

Just 0.6% of the oceans and 6% of territorial seas are protected. Biogeographic classification will help us to understand the distribution of species and habitats for the purposes of scientific research, conservation and management. Compiled by international expert group formed at workshop in Mexico City, January 2007. Made available to Convention on Biological Diversity and UN Ad Hoc Open-ended Informal Working Group studying issues relating to conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction. Download: <http://unesdoc.unesco.org/images/0018/001824/182451e.pdf>

Urban Water Security

Managing Risks

Blanca Jiménez and Joan Rose (eds). Product of UNESCO-IHP project. UNESCO Publishing / Taylor & Francis, ISBN 978-92-3-104063-4, English only, €42.00, 348 pp. Risks include the microbiological and chemical contamination of urban waters and the outbreak of water-borne diseases, mainly due to poor water and sanitation, as well as the discharge of inadequately treated or untreated industrial and domestic wastewater. Climate change exacerbates these problems.

Museum International

Underwater Cultural Heritage

Isabelle Vinson (ed.) Periodical, Volume 60, n° 4, UNESCO Publishing/Blackwell Publishing N° 240, €24.00, ISSN: 1350-0775. Exists in English and French, 112 pp. Takes stock of technological innovations for conserving submerged objects, highlighting maintenance *in situ*. Cautions against the dangers of commercially exploiting underwater cultural heritage. See also *A World of Science*, April 2009.



World Heritage

Earth heritage: A Common Past... and Future

Periodical, number 52, UNESCO Publishing/Pressgroup, ISBN: 92-3-1WH005-2, €5.00. Exists in English, French and Spanish, 116 pp.

Contribution to International Year of Planet Earth. Many World Heritage sites include volcanoes. Other sites boast dramatic karst landscapes, such as the Škocjan Caves (Slovenia) and South China Karst. Also profiles fossil sites and UNESCO's Global Network of National Geoparks.

Learning and Knowing in Indigenous Societies

P. Bates, M. Chuba, S. Kube, D. Nakashima (eds). Local and Indigenous Knowledge Systems (LINKS) programme and Intangible Heritage Section at UNESCO. English only, 128 pp. Commendable efforts are being made to incorporate local knowledge and language content into educational curricula but the relationship and balance between the forms of knowledge remains delicate. Case studies from Botswana, Indonesia, Namibia, Venezuela, etc. Download: <http://unesdoc.unesco.org/images/0018/001807/180754e.pdf>; for details: p.bates@unesco.org

L'atlas mondial des grands singes et leur conservation

J. Caldecott and L. Miles (eds) Produced by UNESCO-MAB in collaboration with UNEP and French Museum national d'histoire naturelle, with government support. French edition of World Atlas of Great Apes and their Conservation (UNEP, 2005). ISBN: 978-92-3-204098-5, 492 pp. (see p. 14)

Soixante ans de science à l'UNESCO : 1945–2005

Produced by Sector of Natural Sciences. French edition of commemorative book published in English in 2006. UNESCO Publishing, ISBN 978-92-3-204005-3, €30.00.

East Asian Biosphere Reserve Network

Produced by UNESCO-MAB. English only, 12 pp. Describes how biosphere reserves in China, Japan, DPR Korea, Rep. of Korea, Mongolia and Russia (also a member of Euro-MAB) are cooperating around three priorities: eco-tourism, conservation and transboundary cooperation. Download: <http://unesdoc.unesco.org/images/0018/001825/182543e.pdf>

Science Programme Activities in Africa (2008–2009)

Produced by UNESCO's Regional Bureau for Science (Nairobi, Kenya), English only, 76 pp. Describes regional activities and those of UNESCO's 11 cluster offices in Africa. Download: <http://unesdoc.unesco.org/images/0018/001817/181746e.pdf>; for details: a.ochanda@unesco.org

