

THE
LITTLE BOOK
OF THE
BIG BANG
A BIG SCIENTIFIC ADVENTURE

Everything you always wanted to know about the **LARGE HADRON COLLIDER** but were afraid to ask

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Science & Technology
Facilities Council

**HOW
DID THE
UNIVERSE
GET TO BE
AS IT IS,**
when it could
all have
been so very
different?



Dear Every-
body,
Nothing
much ever
happens

POST CARD
Everybody
The Earth
The Solar System
The Milky Way
The Universe

A BORING Universe
smoothly, evenly, boringly
the same EVERYWHERE



An INTERESTING Universe



**A VERY
INTERESTING**
Universe, And the
more closely we look
at it the more
interesting it gets.

TRUE!

Most of your body is empty space - very roughly
99.999 999 999 999% NOTHING by volume.
The REST is made of quarks and electrons.

NATURE DOES THINGS...

TADAAA!

Nature doesn't just sit there. Nature DOES things. And that requires forces, such as gravity and electromagnetism. We don't understand a lot of what Nature does.

So far, for example, there is no single and complete theory that can describe all of the forces (gravity, electricity and so on) together. When we have such a theory we will know Nature better. That is one aim of the LARGE HADRON COLLIDER.

The LARGE HADRON COLLIDER is changing the way we think about the Universe.

Doctor
Ron Head

TRUE!

The LARGE HADRON COLLIDER concentrates energy so much that it is as intense as it was one billionth of a second after the start of the Universe, in the BIG BANG.

Some people are so fascinated by the Universe that they're creating a big scientific adventure called the

LARGE HADRON COLLIDER.

It simulates the Universe almost at the beginning of time.

THE LARGE HADRON COLLIDER...



It's **LARGE** so that it can accelerate particles until they have very high energy.

It accelerates beams of **HADRONS.**

Hadrons are particles made of quarks. Protons are one kind of hadron. Mostly the Large Hadron Collider will accelerate protons so that scientists can take a really close look at how Nature does things.

It makes the hadrons **COLLIDE.**

The Large Hadron Collider is at the CERN research centre near Geneva.



TIME, SPACE, ENERGY, FORCES AND STUFF

There are still very
big questions about

STUFF

WHY

is the world made of
matter and not antimatter?

Nobody knows. BUT the LARGE HADRON COLLIDER will put some ideas to the test.

Existing theory says that there were equal amounts of MATTER and ANTIMATTER at the BIG BANG. But nobody knows why we live in a MATTER Universe. The LARGE HADRON COLLIDER will test some ideas.

I am matter. YOU are antimatter



BUT HOW BIG IS IT?

It's hard to tell what's matter and what's antimatter until they meet. Then they annihilate each other, with a bang.

DO WE LIVE IN A WYSIWYG UNIVERSE?

TIME



Tasty to look at...
but if I get the
wrong one I'm
down to my last 8

NTH DIMENSION

We are conscious of space & time, a total of four dimensions. But there could be EXTRA DIMENSIONS that we can't see directly. Maybe the LARGE HADRON COLLIDER will tell us if they exist.



WHAT is dark energy ?

There's a lot of STUFF out there that exerts gravitational pushes and pulls on other STUFF. But it's invisible and NOBODY KNOWS WHAT IT IS. So it gets to be called DARK MATTER. The LARGE HADRON COLLIDER will test predictions about the possible nature of dark matter.



Matter, aka

STUFF
SPACE
ENERGY
FORCES

It takes up

It can store

It affects other matter by means of



Super!

AND symmetric!

If all of nature's forces are just different versions of a single type of interaction then it's likely that for every kind of particle there is a 'SUPERSYMMETRIC' or SUSY partner.

I'm in heaven!

Maybe 'dark matter' is made of SUSY particles. If SUSY particles do exist then the Large Hadron Collider should find them. That might be one mystery solved.



TRY IT AND See



Try it and see. That's something that science does. It uses ideas to develop PREDICTIONS about expected observations.

Then it sets up EXPERIMENTS to TEST the ideas.

Any scientific theory has to stand ready to be questioned and tested. That's what makes scientific theory so strong. Only the best can survive TEST AFTER TEST.

A lot of new ideas have to be thrown out because they do not produce good predictions. But some survive repeated testing.

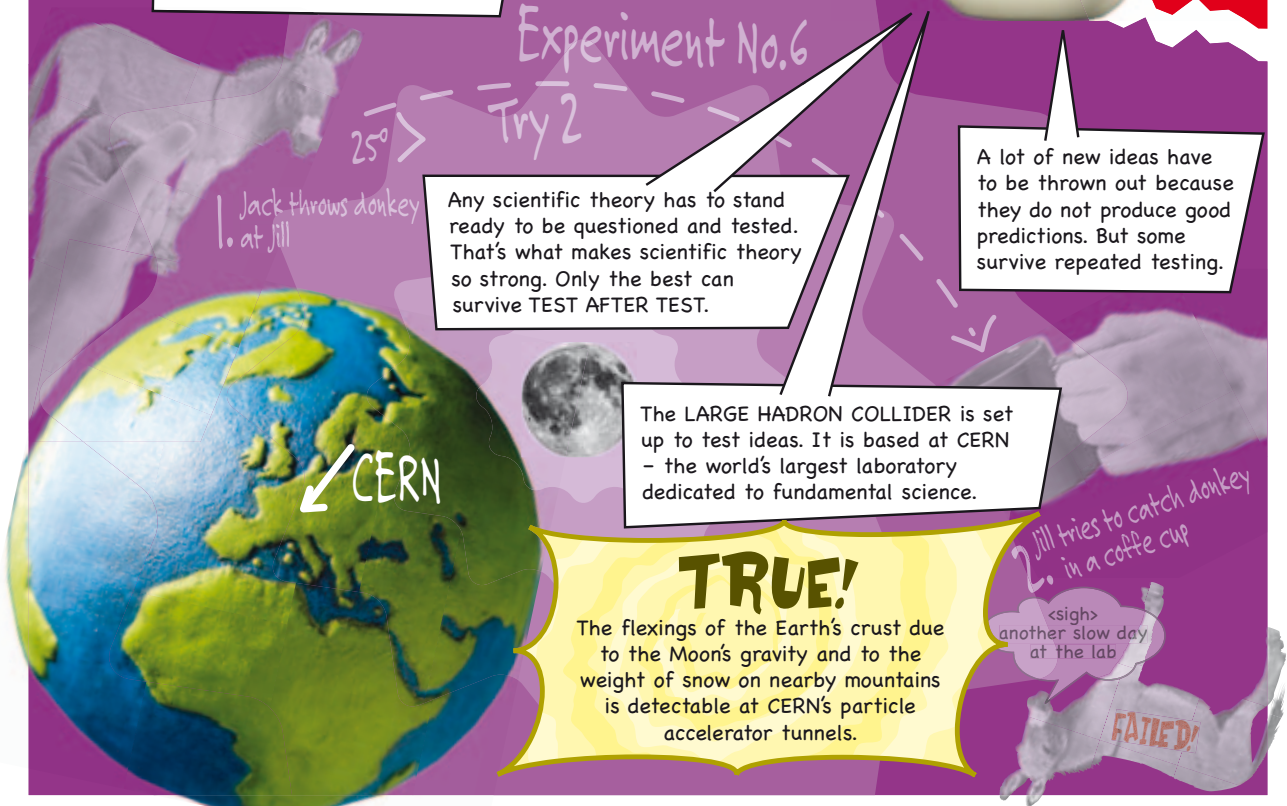
The LARGE HADRON COLLIDER is set up to test ideas. It is based at CERN - the world's largest laboratory dedicated to fundamental science.

TRUE!

The flexings of the Earth's crust due to the Moon's gravity and to the weight of snow on nearby mountains is detectable at CERN's particle accelerator tunnels.

<sigh>
another slow day
at the lab

FATIED!



A MASSIVE PROBLEM REQUIRED A BIG PREDICTION

WHY is there stuff at all?

MASS seems to be a pretty basic feature of matter.

Or to put it another way, why isn't everything as insubstantial as light?

The best ideas about matter, so far, have all had a big failing. They did not predict the existence of MASS as we know it.

So in the 1960s there was an extra IDEA that MASS happens because of the action of a particle that had not yet been detected.

British scientist Peter Higgs had the IDEA and the predicted HIGGS particle was named after him.

To test the PREDICTION that scientists used the LARGE HADRON COLLIDER and in July they found a Higgs-like particle.

Further LHC experiments continue to take place aimed at making certain that the particle is a HIGGS.

Hi



THE LARGE HADRON COLLIDER IS A PEOPLE THING



Scientists explore the fundamental nature of the Universe **BECAUSE IT'S THERE** and because it makes a **COOL JOB**

Like astronomers, scientists at CERN are looking for understanding, rather than new technologies. But because their work is so new they develop new skills and technologies nobody ever needed before. That's how the **WORLD WIDE WEB** began. It began at CERN.

Who knows what new skills and expertise will emerge in the future.



LYN EVANS

Lyn, from Aberdare in Wales, has worked on accelerators at CERN for over 30 years and was the LHC project leader before more recently being appointed to lead the international effort to design the world's next major particle collider. Lyn is the Linear Collider Director and will lead the Linear Collider organization created to bring two existing large-scale linear collider programs under one governance and build on the work of the LHC.



DAVE BARNEY

Dave joined CERN after completing a PhD at Imperial College, London in 1994. Since then he has worked on the CMS experiment where he is director of outreach CMS.

"I'm also the co-ordinator for public outreach.

I'm married to Jane and have two young children – Stephanie and Robert. I enjoy playing football (with a local French veterans team!) and skiing."

ALISON BATES

Alison, from the University of Glasgow, has spent the last few years based at CERN helping to build the LHCb detector.

"LHCb will be looking at the differences between matter and antimatter. It is one of the smaller experiments at the LHC, but certainly not the least exciting. I have really enjoyed the experience of being at CERN and being involved with the LHC, and it has definitely improved my skiing!"



LILY ASQUITH

Lily Asquith is a physics postdoctoral student at Argonne National Laboratory in Chicago. She works on data from the ATLAS particle detector at CERN's Large Hadron Collider. She has been actively involved in the search for the Higgs particle.

"I love what I'm doing – looking for fundamental truths – and I get to plan my own work and travel all over the place!"

THE LARGE HADRON COLLIDER IS A GLOBAL THING



The work of CERN is all about international cooperation, not international confrontation.

Countries share the costs, and the benefits.



TRUE!

Every aspect of CERN is international. Firefighters at CERN come from Bulgaria, The Czech Republic, Finland, France, Germany, The Netherlands, Italy, Spain and the UK.

PEOPLE WORKING AT CERN COME FROM 98 DIFFERENT COUNTRIES

CERN has a huge global impact.

It involves a LOT of people.

It develops new technology (like the WORLD WIDE WEB).

It changes THE WAY WE THINK.

But it only costs the same to run as one large hospital.

CERN and the
LARGE HADRON COLLIDER



wow
wow
wow
wow

CERN began work in 1954, bringing countries of Europe together after the horrors of World War II. Since then, people from 151 different countries have worked there at one time or another.

TRUE!

As well as the WORLD WIDE WEB, X-ray and radiopharmaceutical techniques in medical imaging were developed by particle physicists.

FROM THE BIKE

In the early days...

In the 1960s scientists at CERN sent tapes of experimental data to their computer centre by BICYCLE.

NEW
improved file
transfer speeds
(now has 3 gears!)

... later ...

CERN scientists developed the **WORLD WIDE WEB** so that they could communicate with each other, all over the world.

TRUE!

British industry is involved in state-of-the-art technologies - making precision electronic, magnetic and vacuum components for the LHC



I go faster than that

TO THE WEB

... now, and for the future

Working out what's happening in the Large Hadron Collider's huge detectors will need a LOT of computer activity.

TO THE GRID

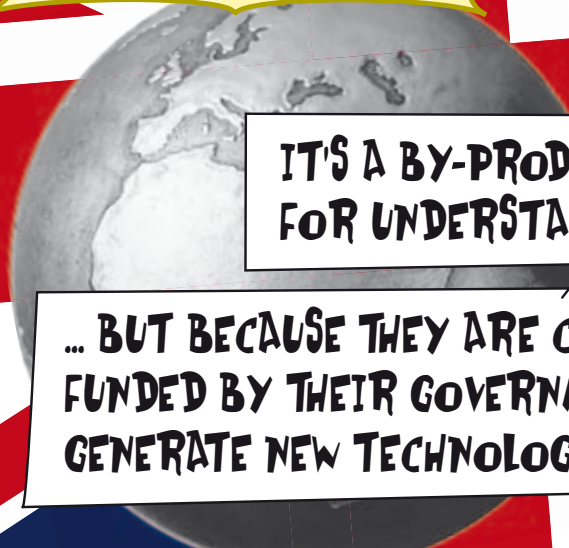
So scientists have developed THE GRID - a global network of computers becoming one huge interconnected machine.

TRUE!

British taxpayers each contribute the cost of a couple of loaves of bread each year to this world-leading project.

IT'S A BY-PRODUCT OF SCIENTISTS' SEARCHES FOR UNDERSTANDING OF NATURE ...

... BUT BECAUSE THEY ARE CLEVER, DETERMINED AND FUNDED BY THEIR GOVERNMENTS THEY ARE ABLE TO GENERATE NEW TECHNOLOGIES.



FURTHER INFORMATION

If you would like to know more about the LHC and the science behind it, try the following resources:

WORLD WIDE WEB SITES

www.cern.ch

www.collidingparticles.com

www.oxfordsparks.net/animations/lhc

TWITTER

@CERN

@ATLASexperiment

@CMSexperiment

@LHCbExperiment

@ALICEexperiment

BOOKS

Collider - the search for the world's smallest particles
Paul Halpern, John Wiley & Sons, 2009

The Quantum Frontier - The Large Hadron Collider
Don Lincoln, Johns Hopkins University Press, 2009

The Large Hadron Collider a Marvel of Technology
edited by Lyndon Evans, EPFL, 2009

A Zeptospace Odyssey (A journey into the Physics of the LHC)
Gian Giudice, OUP Oxford, 2010

Present at the Creation (Story of CERN and LHC)
Amir Aczel, Crown, 2010

Massive - The Hunt for the God Particle
Ian Sample, Virgin Books, 2011

The Infinity Puzzle
Frank Close, OUP Oxford, 2011

Knocking on Heaven's Door
Lisa Randall, Vintage, 2012

Higgs Force
Nicholas Mee, Lutterworth, 2012

The Science and Technology Facilities Council operates world-class, large-scale research facilities; supports scientists and engineers world-wide; funds researchers in universities and provides strategic scientific advice to government.

The Council's Science in Society unit offers a wide range of support for teachers, scientists and communicators to facilitate greater engagement with STFC science which includes astronomy, space science, particle physics and nuclear physics:

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For further information telephone 01793 442175 or email neville.hollingworth@stfc.ac.uk



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