Actually Existing Science

Up until now I have tried to describe

- what features of the physical world science can investigate
- the methodology that science uses
- how we can decide if the results of science represent some kind of objective reality.

This is the description of an ideal

How does science work in the real world?

SCIENCE IN THE REAL WORLD

SCIENCE IS DONE IN THE REAL WORLD

- MONEY
- POLITICS
- ETHICS

EVEN IF THE POST-MODERNISTS ARE WRONG ABOUT MOST THINGS, THEY ARE CORRECT ABOUT ONE THING

SCIENCE IS DONE BY REAL PEOPLE IN A REAL SOCIETY → SOCIOLOGY OF SCIENCE

SOCIOLOGY OF SCIENCE ENCOMPASSES!

PSYCHOLOGY

HISTORICAL EFFECTS

POLITICS

ETHICS

ORGANIZATION

WORK METHODS

SOME OF THESE WILL BE COMMON TO ALL SCIENCES

BUT SOME WILL VARY ENORMOUSLY:

LIFE SCIENCE

CONDENSED MATTER PHYSICS

PARTICLE PHYSICS

Sociology of Science Should Answer Questions!

Is science as an enterprise

- well organized?
- equiped to deliver truth?
- of benefit to humanity?
- Does the history of the scientific enterprise tell us any of general interest about human society?

HISTORICAL ORIGIN OF SCIENCE

TODAY, SCIENCE IS A UNIVERSAL HUMAN ACTIVITY / EXPERIENCE, ALL SOCIETIES CONTRIBUTE

EXAMPLES OF "PROTOSCIENCE" GO BACK MILLENIA & SEEM TO BE FAIRLY CULTURALLY INDEPENDENT

EXPONENTIAL GROWTH OF SCIENCE FROM GALILEO – STARTED IN THE WEST

WAS THIS JUST A HISTORICAL ACCIDENT?

OR WAS IT DUE TO THE CHANGING SOCIETAL ORGANISATION?

MANY (CONFLICTING) OPINIONS AVAILABLE

EXISTENCE OF "SCIENCE-LIKE" BELIEF SYSTEMS

WHY DO PSEUDO-SCIENCES EXIST AND PROSPER IN THE FACE OF SCIENTIFIC REFUTATION?

ALCHEMY
ASTROLOGY
HOMO PATHY
OSTEOPATHY
LYSENKOIST BIOLOGY
RACISM
CREATION SCIENCE
SCIENTOLOGY

→ WE'LL TALK ABOUT PSEUDO SCIENCE IN ANOTHER LECTURE

FRANKLIN GIVES THE INTERESTING EXAMPLE OF MEDICINE BEFORE ANTIBIOTICS & OTHER MODERN DEVELOPMENTS

NOT CLEAR THAT MEDICINE DID ANYONE MUCH GOOD

"ONE DOCTOR, SINGLY LIKE A SCULLER PLIES
THE PATIENT STRUGGLES & BY INCHES DIES
BUT TWO PHYSICIANS LIKE A PAIR OF OARS
WAFT HIM SWIFTLY TO THE STYGIAN SHORES"

GUILLAUME DE SALLUSTE
DU BARTAS 1544–1590

YET PHYSICANS WERE WELL RESPECTED

"THE SIMPLICITY OF TRUTH IS ANNOYING TO MAN" GOETHE

FRANKLIN QUOTES A STUDY GIVING THE PROFILE OF A TYPICAL SCIENTIST. IF FACT THIS WAS A STUDY OF AUTISTIC PEOPLE IN THE PHYSICAL SCIENCES

FAR FROM BEING "TYPICAL", I THINK THE LISTED ATTRIBUTES ARE CULTURALLY DETERMINED.

THE PREDOMINANCE OF MALES IN MATHEMATICS & PHYSICS HAS BEEN THE SOURCE OF MUCH FRUITLESS DEBATE ON NATURE VERSUS NURTURE

BUT SOME OBVIOUS ATTRIBUTES OF SCIENTISTS CAN BE IDENTIFIED.

PSYCHOLOGICAL SKILLS NEED IN SCIENCE

- PERSISTENCE
- PATIENT
- COORDINATION OF THEORY & EVIDENCE
- ABILITY TO SEPARATE THEORY & EVIDENCE
  ABSTRACT THINKING
- APPRECIATE THAT THEORIES WHETHER YOU FAVOUR THEM OR NOT HAVE EVIDENCE BOTH FOR / AGAINST
- ABILITY TO SUSPEND BELIEF / COMMITMENT WHEN ASSESSING EVIDENCE

AS FAR AS PUBLIC POLICY GOES, MOST PEOPLE AGREE THAT THERE SHOULD BE PROGRAMS TO IDENTIFY & ENCOURAGE CHILDREN IN ALL GROUPS WHO SHOW AN INTEREST IN SCIENCE

CERTAINLY OVER THE PAST 20 YEARS THIS HAS BEEN PURSUED IN ALL DEVELOPED COUNTRIES

FUNDING OF SCIENCE

MOST SCIENCE IS NOW TOO EXPENSIVE TO BE PRIVATELY FUNDED!

ATLAS @ LHC IN CANADA (GAVE YOU M_{Higgs})

~ $40 MILLION CONSTRUCTION
~ $60 MILLION IN OPERATIONS TO DATE ($5M/YEAR)

COMPARE INTERNATIONAL BUDGET OF ATLAS

~ $1 BILLION

LHC ~ $10 BILLION

DIFFICULT TO ESTIMATE ACTUAL COST

DIFFERENT COUNTRIES CALCULATE COSTS IN DIFFERENT WAYS.

IS SCIENCE EXPENSIVE?

THESE LOOK LIKE BIG NUMBERS

HOW DO THEY COMPARE TO OTHER THINGS THAT SOCIETY SUPPORTS?

US CONTRIBUTION TO LHC ~ $4 BILLION

HUBBLE SPACE TELESCOPE ~ $1.5 BILLION

SPACE SHUTTLE PROGRAM ~ $196 BILLION

US DEFENCE SPENDING ~ $680 BILLION

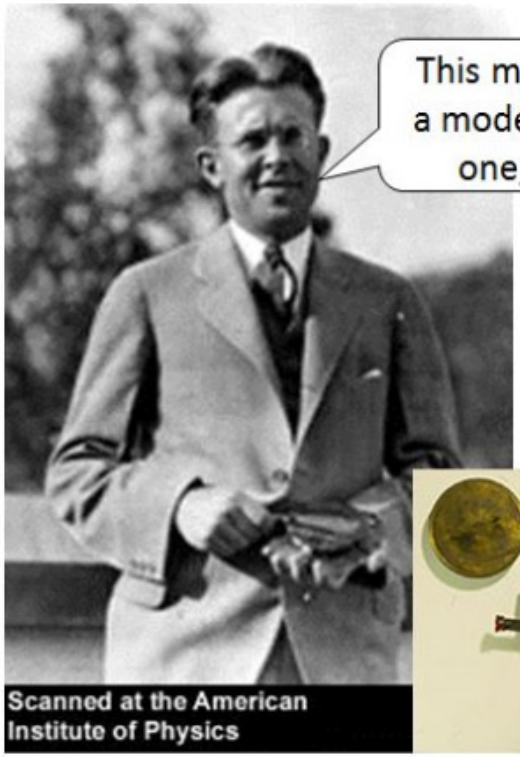
US HEALTH CARE ~ $1300 BILLION

INTERNATIONAL SCIENCE FUNDING (2010)

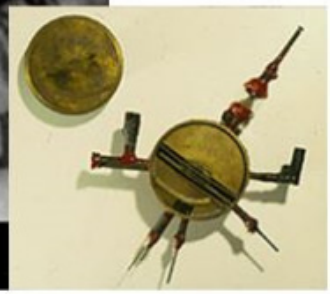
	$ x 10^9	% GDP	
US	405	2.7	←
CHINA	296	2.0	
JAPAN	160	3.7	←
GERMANY	70	2.3	
SOUTH KOREA	56	3.7	←
FRANCE	42	1.9	
U K	38	1.7	
INDIA	36	0.9	
CANADA	24	1.8	
TAIWAN	19	2.3	
AUSTRALIA	16	1.7	
ISRAEL	9.4	4.2	←
SINGAPORE	6.3	2.2	

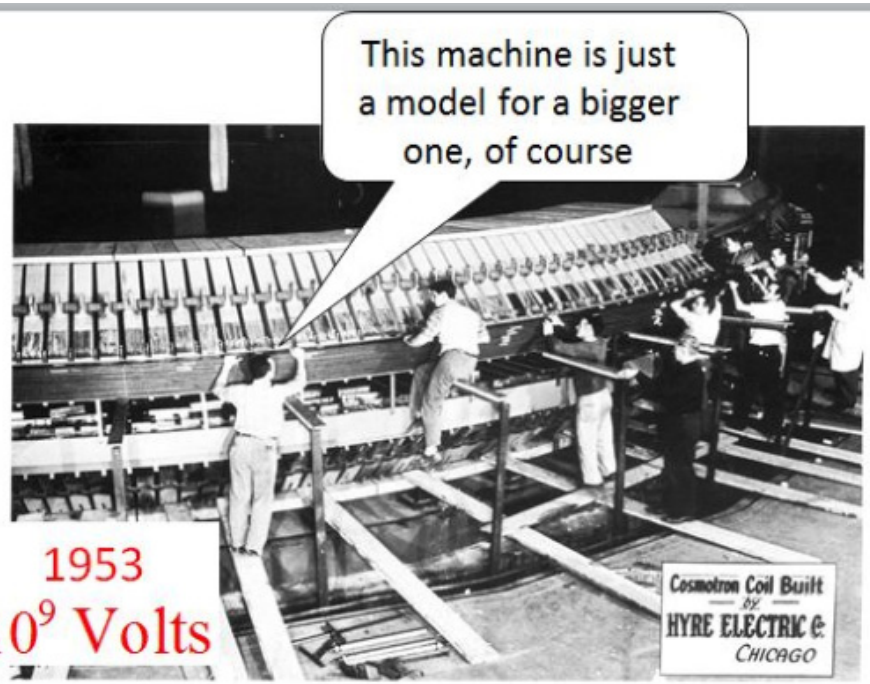
- IN THE DISTANT PAST SCIENTISTS DEPENDED ON RICH PATRONS GALILEO - ---
- MORE RECENTLY FUNDED UNIVERSITIES
- ADVENT OF BIG SCIENCE IN 1930s IN US
  E.O. LAWRENCE — INDUSTRIAL PHILANTHROPY
- DURING & SINCE, WORLD WAR II, PURE SCIENCE FUNDING HAS BEEN LARGELY FROM GOVERNMENTS.

CLEARLY THIS SUBJECTS SCIENCE TO A RANGE OF SOCIAL, POLITICAL, & FINANCIAL PRESSURES UNKNOWN TO EARLIER SCIENTISTS



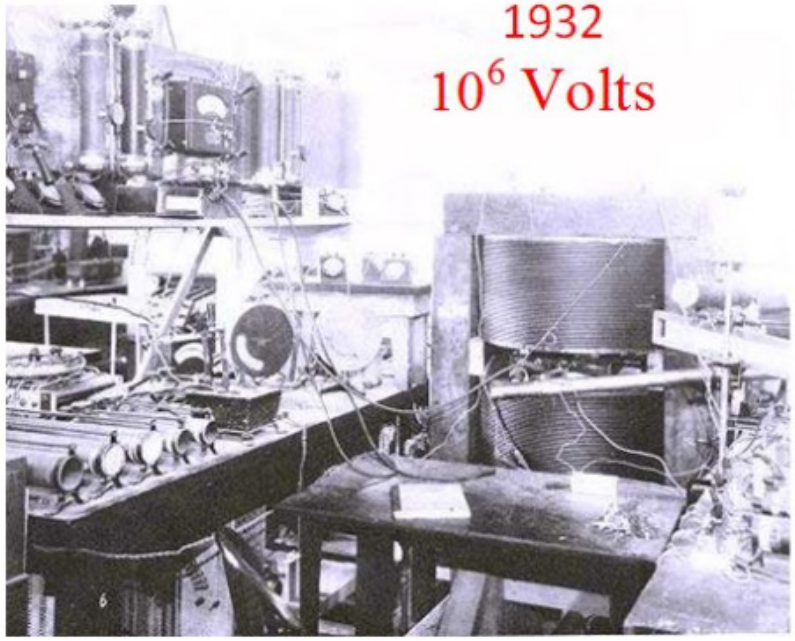
1931
10^4 Volts

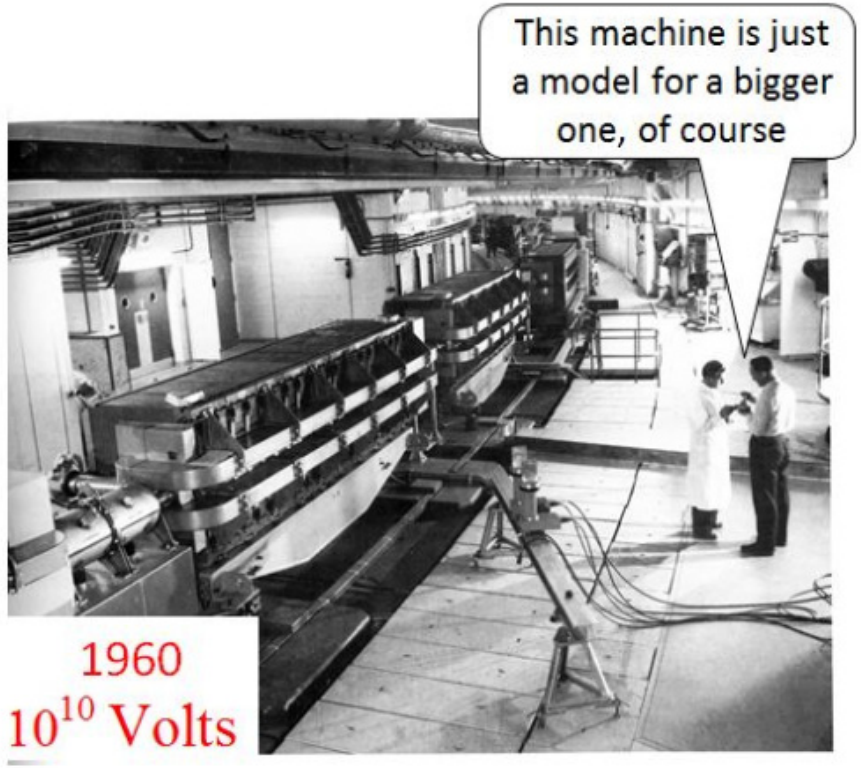




1953
10^9 Volts

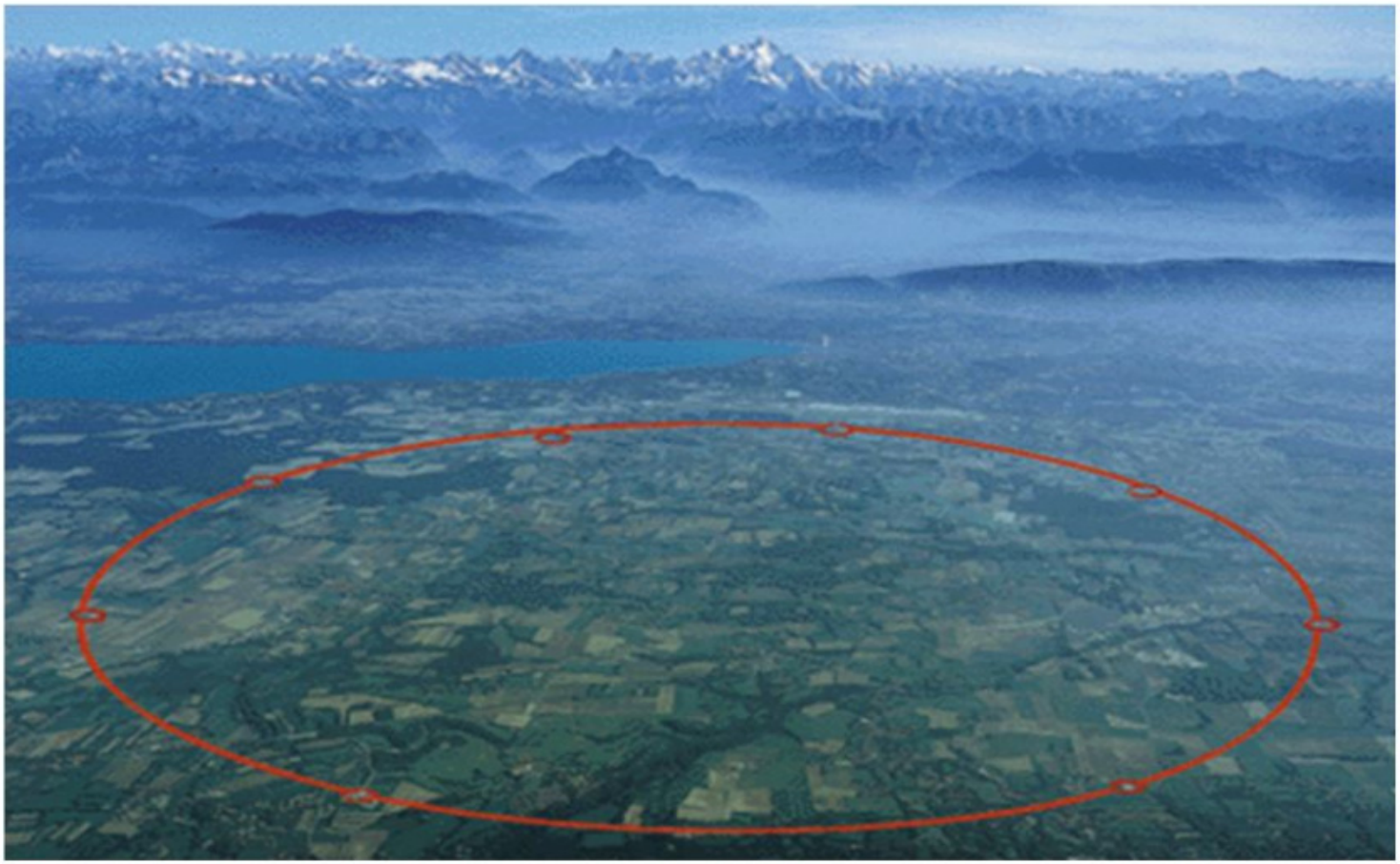
1932
10^6 Volts





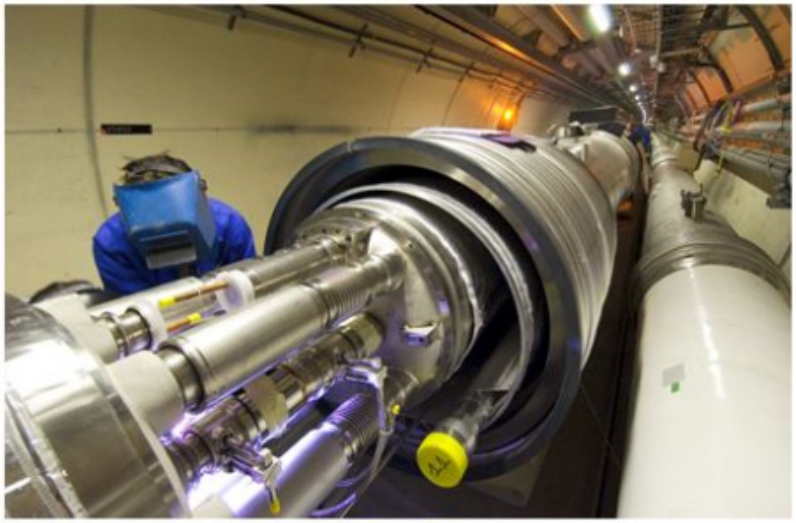
1960
10^{10} Volts

CERN Seen from the Air

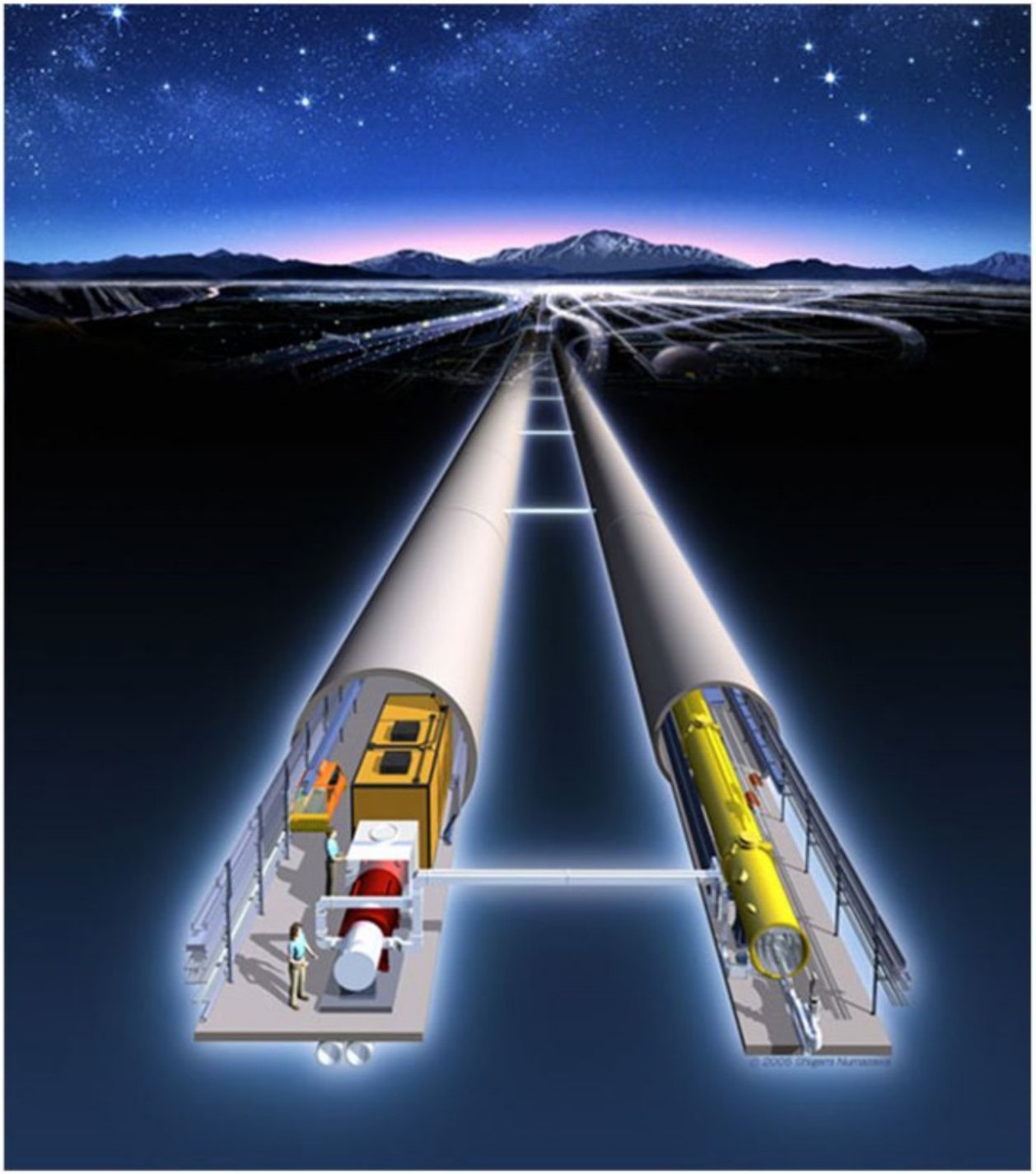


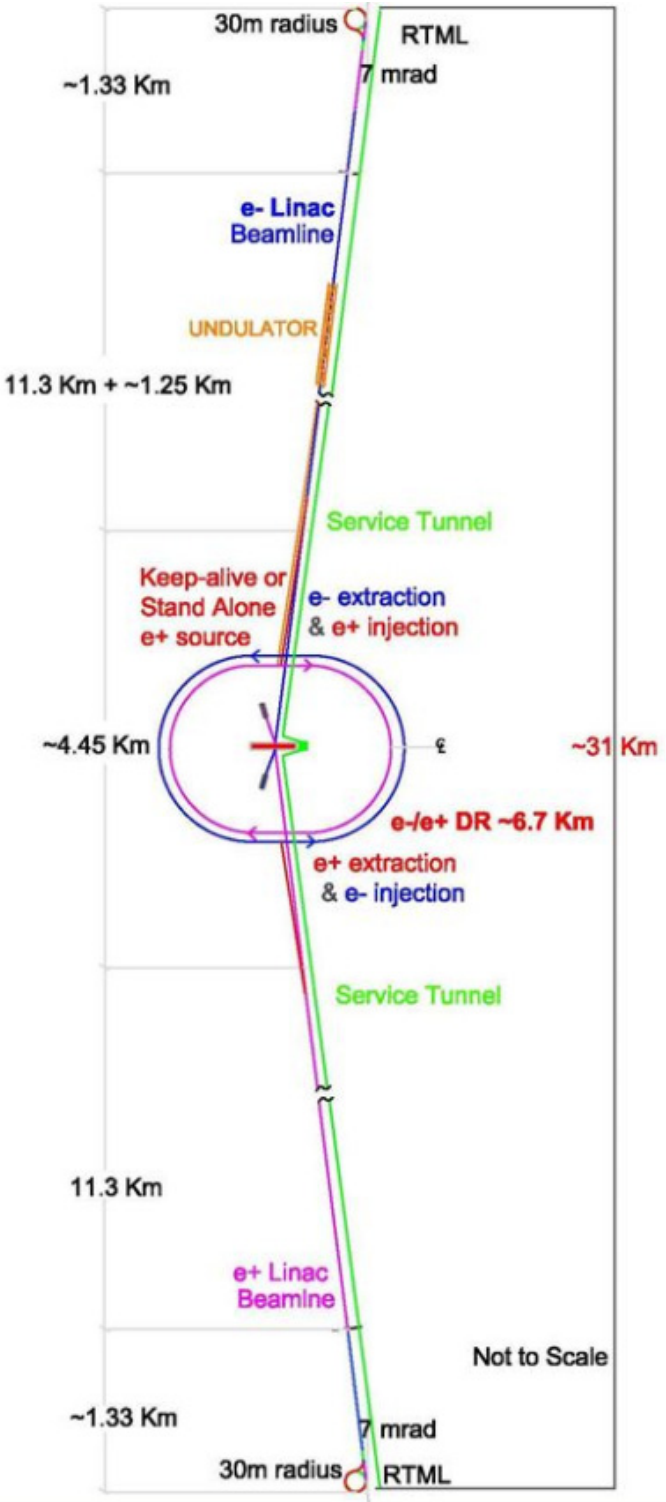
- Tunnels of CERN accelerator complex superimposed on a map of Geneva.
- Accelerator is 50 m underground
- 25 km in circumference

Underground

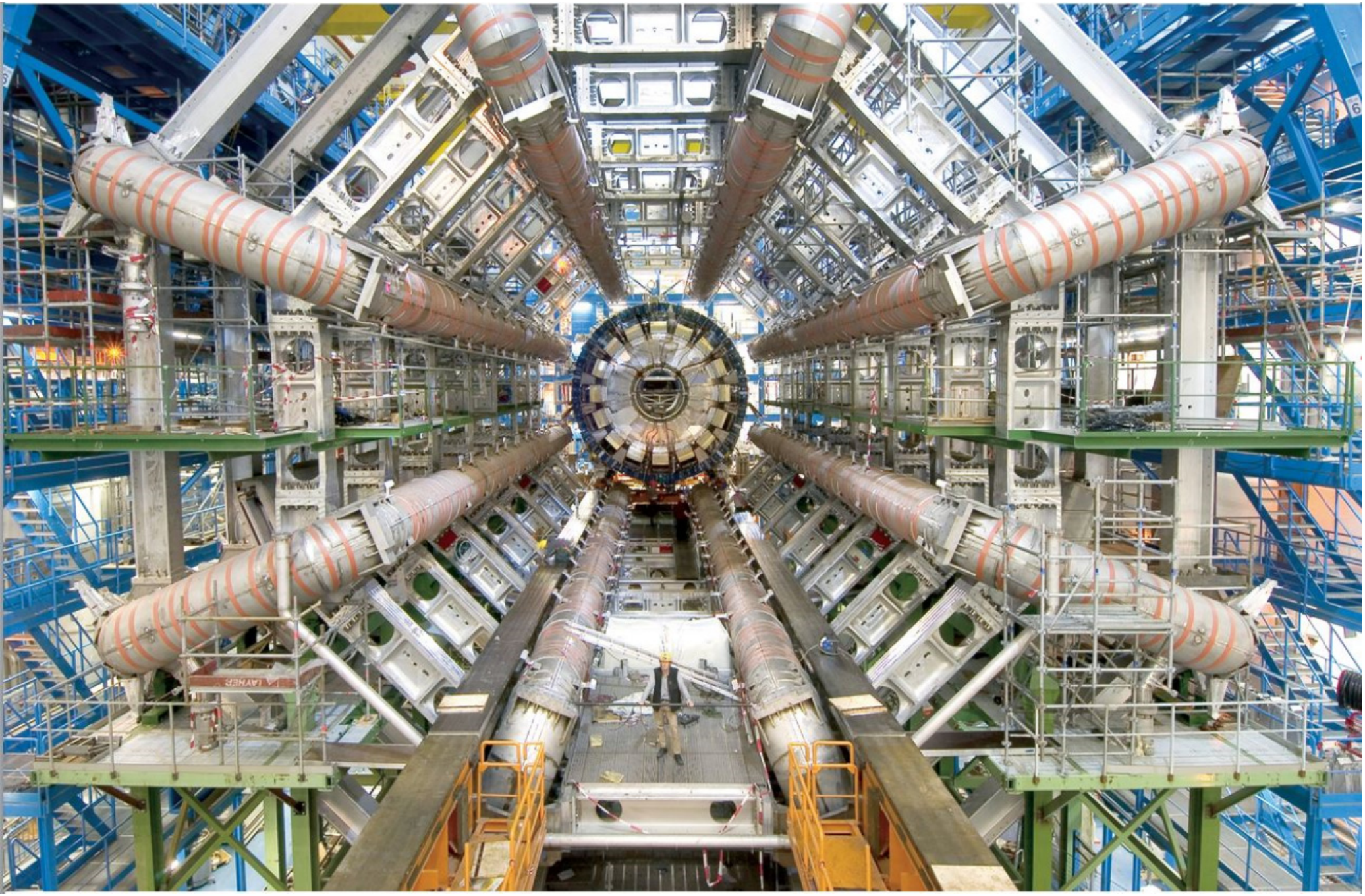



Alors, c'est fini!
Et maintenant?




30m radius
RTML
7 mrad
~1.33 Km
e- Linac
Beamline
UNDULATOR
11.3 Km + ~1.25 Km
Service Tunnel
Keep-alive or
Stand Alone
e+ source
e- extraction
& e+ injection
~4.45 Km
~31 Km
e-/e+ DR ~6.7 Km
e+ extraction
& e- injection
Service Tunnel
11.3 Km
e+ Linac
Beamline
Not to Scale
~1.33 Km
7 mrad
30m radius
RTML


Argentina
Armenia
Australia
Austria
Azerbaijan
Belarus
Brazil
Canada
Chile
China
Colombia
Czech Republic
Denmark
France
Georgia
Germany
Greece
Israel
Italy
Japan
Morocco
Netherlands
Norway
Poland
Portugal
Romania
Russia
Serbia
Slovakia
Slovenia
South Africa
Spain
Sweden
Switzerland
Taiwan
Turkey
UK
USA
CERN
JINR
ATLAS
Collaboration
July 2010

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M
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Funding Mechanism

Usual funding method is competitive grants from government funding agency in Canda Natural Sciences & Engineering Research Council (NSERC)

- individual (or team) makes a written application to funding agency
  - Proposal gives description of research plan & requested budget
  - Track record of applicants in science
  - Track record in educating graduate students.

AT LEAST IN CANADA, APPLICATIONS ADJUDICATED BY A TEAM OF EXPERTS!

- PEER REVIEW
- INTERNATIONAL MEMBERSHIP

FUNDING USUALLY FOR 3-5 YEARS

MAIN DOWNSIDE IS THAT REVIEWERS MUST HAVE SUFFICIENT KNOWLEDGE

→ TEND TO BE FRIENDS (OR ENEMIES) OF APPLICANTS

- FOR LARGE PROJECTS IN CANADA DIFFICULT TO FIND "ARM'S LENGTH" CANADIANS.

MAY END UP WITH ADJUDICATION BY NON-EXPERTS IN THE FIELD.

GOVERNMENT INFLUENCE

CLEARLY THERE IS GOVERNMENT INFLUENCE ON WHAT SCIENCE IS FUNDED

THIS IS OK IN A DEMOCRACY – GOVERMENT REPRESENTS TAXPAYERS.

GOVERNMENTS TEND TO FAVOUR APPLIED RESEARCH → BANG FOR THE BUCK.

HEALTH CARE

ENVIROMENT

ENERGY SOURCES

NANOTECHNOLOGY

BUT THERE IS A RECOGNITION, BY MOST GOVERNMENTS THAT CURIOSITY DRIVEN RESEARCH

— CULTURE

— TECHNICAL SPIN OFFS

EXAMPLE — HIGH ENERGY PHYSICS

- LARGE SCALE APPLICATION OF SUPER CONDUCTIVITY

— HIGH SPEED ELECTRONICS

— EMBEDDED SYSTEMS

— NETWORKING → WWW

— LARGE PROJECT ORGANIZATION

— SOFTWARE ENGINEERING

— TECHNICALLY EDUCATED PEOPLE

"DIRECTED" RESEARCH

GOVERNMENTS OFTEN BELIEVE THAT THEY CAN FUND RESEARCH LEADING TO NEW ECONOMIC DEVELOPMENT

SINCE POLITICIANS AND CIVIL SERVANTS ARE RARELY SCIENTISTS → WHY SHOULD THEY BE ABLE TO PREDICT WHAT WILL BE A SUCCESS?

MICROSOFT
FACE BOOK
GOOGLE
INTEL
↳ NOT "SEEDED" BY US GOVERNMENT

EXCEPTIONS!
ANGELA MERKEL
MARGARET THATCHER
STEPHEN CHU
MARK OLIPHANT

* INMOS (FAILED) "SEEDED" BY UK GOVERNMENT

ANOTHER PROBLEM WITH THIS FUNDING MODEL

→ ECONOMIC BENEFITS ACCRUING FROM PURE SCIENCE TEND NOT TO LEAD TO A FLOW OF FUNDS BACK INTO PURE SCIENCE

eg WWW → CERN

BUSINESS & GOVERNMENTS DO NOT TRY TO REIMBURSE PURE SCIENCE ESTABLISHMENTS → NOT CLEAR WHAT MECHANISM COULD ACHIEVE THIS

INDUSTRIAL RESEARCH

DIRECT PAYBACK IS POSSIBLE IF SCIENTISTS IN A COMPANY PRODUCE PATENTABLE RESEARCH

MANY IMPORTANT DEVELOPMENTS — OVERLAP WITH PURE SCIENCE

GENERAL ELECTRIC → ELECTRIC LIGHT
SOLID STATE LASER
COMPUTED TOMOGRAPHY

RCA (DEFUNCT) → ELECTRONIC TV
COLOUR TV
VIDEO CAMERAS

BELL → TRANSISTOR
LAZER
CCD
INFORMATION SCIENCE
C, C++

IBM → HIGH T_c SUPERCONDUCTIVITY

AI

FORTRAN

FRACTAL GEOMETRY

SONY, SAMSUNG, SEIMANS, PANASONIC ETC.

BASIC IDEAS CANNOT BE PATENTED

CAN'T PATENT MAXWELL'S EQUATIONS

CAN YOU PATENT A GENOME?

LIFE SCIENCES DO WELL

→ PHARMACEUTICALS

→ BIOTECHNOLOGY

PUBLICATION OF RESULTS

SCIENCE ADVANCES BY BUILDING ON EXISTING KNOWLEDGE & AND SHARING IDEAS.

SCRUTINY OF RESULTS → IMPORTANT PART OF SCIENCE

- LEAD TO NEW IDEAS
- COMMUNITY SELF-CORRECTS ERRORS & FRAUD.

THE PRODUCTION OF A PAPER CAN RANGE FROM INDIVIDUALS → HUGE TEAMS IN PARTICLE PHYSICS

IN THIS CASE RESULTS CRITICALLY REVIEWED WITHIN THE COLLABORATION

PEER REVIEW

THIS IS A CRUCIAL MECHANISM IN ENSURING THAT SCIENCE PRODUCES TRUTH.

ANYONE CAN CALL A PRESS CONFERENCE, OR PUT THEIR IDEAS IN A BLOG

WE ONLY COUNT AS ACCREDITED SCIENCE RESULTS WHICH APPEAR IN A PEER REVIEWED JOURNAL

— RESULTS WHICH HAVE UNDERGONE

— SCRUTINY

— "VERIFICATION"

PEER REVIEW PROCESS

- EDITOR MAKES AN INITIAL JUDGEMENT
- IF POSITIVE SENDS TO ANONYMOUS REFEREES
  - FRANKLIN SAYS 'WITHOUT AUTHORS' NAMES ATTACHED" - THIS CANNOT BE DONE IN BIG SCIENCE - EVERYONE KNOWS THAT A "HIGGS PAPER" COMES FROM ATLAS/CMS
- REFEREES JUDGE
  - CORRECTNESS
  - ORIGINALITY
  - SIGNIFICANCE
- PAPER
  - REJECTED
  - ACCEPTED
  - ACCEPTED SUBJECT TO REVISION

→ LEADS TO "CONVERSATION" BETWEEN ANONYMOUS REFEREES & AUTHOR(S) USUALLY IMPROVES QUALITY OF PAPER

HIERARCHY OF JOURNALS

- SOME JOURNALS MORE HIGHLY REGARDED THAN OTHERS
  SCIENCE, NATURE, PHYSICAL REVIEW LETTERS
- IT IS MORE PRESTIGIOUS TO GET PUBLISHED IN ONE OF THESE → CAREER POINTS
- JOURNALS LIKE THESE HAVE STRICTER REFEREEING STANDARDS (ONE HOPES)
- THESE TOP JOURNALS MAY ONLY ACCEPT 2-3% OF SUBMISSIONS
- MOST REJECTED PAPERS PUBLISHED IN LESS PRESTIGIOUS JOURNALS → NOT "WRONG" JUST "LESS URGENT / INTERESTING"

REFEREEING PLAINLY NECESSARY → CREDIBILITY

IF A PAPER HAS PASSED SCRUTINY OF OBJECTIVE EXPERTS → PROBABLY CORRECT

PSEUDOSCIENCE NOT SUBJECTED TO REFEREEING → WHICH IS PARTLY WHY IT REMAINS PSEUDOSCIENCE

REFEREEING WORKS WELL IN MATHS, WHERE THE REFEREE CAN REPRODUCE THE RESULTS

→ NOT SO CLEAR IN OTHER SUBJECTS

REFEREEING PROBABLY WORKS THROUGH LONG TERM DETERENCE – THE FEAR OF BEING EXPOSED TO CENSURE OR RIDICULE

RATHER THAN BY A PROCESS OF HANDS-ON VERIFICATION.

FLAWS IN PEER REVIEW

MAIN FLAW IS THAT REFEREES DO IT FOR FREE

JOURNALS DO NOT PAY AUTHORS OR REFEREES

BUT CHARGE LARGE AMOUNTS TO UNIVERSITY LIBRARIES → YOU GET WHAT YOU PAY FOR

→ HOW COMMITTED ARE REFEREES?

NEW DEVELOPMENTS

→ OPEN ACCESS (= FREE)

— ARXIV.ORG YOU CAN SUBMIT A PAPER IF YOU REGISTER

SUBJECT TO MODERATION BY VOLUNTEER COMMITTEE

FOR A GIVEN PAPER, THE MOST QUALIFIED REFEREE

— MAY BE TOO BUSY

— MAY BE SUBJECTIVE (DISLIKES AUTHOR)

RECENTLY THERE IS EVIDENCE THAT SOME PUBLISHED RESULTS MAY JUST BE STATISTICAL FLUCTUATIONS

THIS SEEMS TO BE ESPECIALLY TRUE IN THE MEDICAL SCIENCES

IN 2011 ONLY 65% OF MEDICAL SCIENCE RESULTS WERE CONSISTENT WHEN REDONE

ONLY 6% WERE COMPLETELY REPRODUCIBLE

eg STEM CELL RESEARCH OF WOO SUK HWANG

REFEREEING EXPERIMENTAL WORK IS VERY DIFFICULT.

REFEREES DO NOT USUALLY HAVE TIME OR FACILITIES TO REPRODUCE RESULTS

THEY ADJUDICATE BASED ON:

- LOOKS REASONABLE
- ESTABLISHED REPUTATIONS

IN PARTICLE PHYSICS REFEREES CANNOT REALLY JUDGE WORK OF 4000 PEOPLE @ LHC

→ INTERNAL REFEREE PROCEDURE

↓

WORKS WELL

US SUPREME COURT IN 1993 LAID DOWN STANDARDS OF QUALITY FOR SCIENTIFIC RESEARCH USED AS EVIDENCE IN COURT

1) CAN THEORY OR TECHNIQUE TESTED — FALSIFIABLE

2) WHETHER THEORY OR TECHNIQUE HAS BEEN SUBJECTED TO PEER REVIEW & PUBLICATION

3) WHETHER RATE OF ERROR IS KNOWN & SMALL

4) EXISTENCE & MAINTENANCE OF STANDARDS CONTROLLING OPERATION OF TECHNIQUE

5) WHETHER TECHNIQUE IS GENERALLY ACCEPTED BY THE SCIENTIFIC COMMUNITY

① + ③ → LOGIC ② + ④ + ⑤ SOCIOLOGY

QUOTATION FROM EDITOR OF "LANCET"

"WE PORTRAY PEER REVIEW TO THE PUBLIC AS A QUASI-SACRED PROCESS THAT MAKES SCIENCE OUR MOST OBJECTIVE TRUTH TELLER. BUT, WE KNOW THE SYSTEM OF PEER REVIEW IS BIASED, UNJUST, UNACCOUNTABLE, INCOMPLETE EASILY "FIXED", OFTEN INSULTING, USUALLY IGNORANT, OFTEN FOOLISH, AND FREQUENTLY WRONG"

SOCIOLOGY OF SCIENCE – ATTRACTING A NEW GENERATION

AS SCIENCE HAS BECOME MORE COSTLY SCIENTIST HAVE BECOME MORE AWARE OF THE NECESSITY OF OUTREACH TO PUBLIC

NATIONAL & INTERNATIONAL LABORATORIES HAVE PROFESSIONAL PUBLIC RELATIONS DEPARTMENTS

- → PRESS RELEASES
- → MAGAZINES
- → NETWORKS → QUARKNET
  ATLAS MASTERCLASS
- → "TRAINING" OF SCIENTISTS IN HOW TO RESPOND TO INTERVIEWS

THE PUBLIC PAYS FOR SCIENCE THEY HAVE A RIGHT TO KNOW WHERE THEIR MONEY GOES

MANY CURRENT PUBLIC POLICY ISSUES INVOLVE WHAT ARE ACTUALLY SCIENTIFIC ISSUES

- CLIMATE CHANGE
- ENERGY SOURCES
- DEFENCE
- TRANSPORTATION
- PUBLIC HEALTH

A PUBLIC WHICH UNDERSTANDS HOW TO MAKE RATIONAL SCIENTIFIC DECISIONS IS THE ONLY REAL HOPE FOR ENSURING SENSIBLE POLICIES.

TECHNOLOGICAL FUTURE

CLEARLY, THERE EXISTS A POSSIBLE RANGE OF PROJECTIONS FOR THE FUTURE OF OUR SOCIETIES → IF THE PAST IS ANY GUIDE TECHNOLOGICAL ADVANCE WILL ACCELERATE

WILL IT BE BASED ON PURE SCIENCE?

I THINK SO. CERTAINLY LIFE SCIENCES WILL CHANGE THE WAY WE LIVE (& DIE!)

WILL THERE BE INTELLIGENT MACHINES?

WILL WE UNDERSTAND THE HUMAN BRAIN IN WAYS THAT WE CAN BOOST INTELLIGENCE?

THE FUTURE WILL CERTAINLY BE DIFFERENT FROM THE PAST

WILL PHYSICAL SCIENCE INFLUENCE THE FUTURE?

WHILE ONE CAN IMAGINE (PERHAPS FEAR) HOW LIFE SCIENCES WILL CHANGE THE FUTURE.

WHAT ABOUT PHYSICS? HARDER TO SAY

WE HAVE SPENT ~150 YEARS ON THE PRACTICAL APPLICATIONS OF MAXWELL'S EQUATIONS

ABOUT 100 YEARS ON PRACTICAL APPLICATIONS OF QUANTUM MECHANICS

PRACTICAL APPLICATIONS WILL GO ON

→ NEW MATERIALS

WILL A MORE FUNDEMENTAL UNDERSTANDING OF SPACE & TIME LEAD TO NEW DEVELOPMENTS?

→ I THINK SO

THE NEXT GENERATION

COMPARED TO OTHER COUNTRIES THE STUDY OF PHYSICAL SCIENCE IS LESS POPULAR AT NORTH AMERICAN UNIVERSITIES

PROBABLY WILL ALWAYS BE TRUE → HARD OUTREACH IS IMPORTANT → WE HAVE TO ATTRACT EVERY INTERESTED / TALENTED YOUNG PERSON → ESPECIALLY FROM "NON TRADITIONAL" GROUPS

ETHICAL ISSUES

SCIENCE IS CONCERNED WITH TRUTH

→ HOW CAN THERE BE ETHICAL ISSUES?

"YOU SHALL KNOW THE TRUTH

AND THE TRUTH SHALL SET YOU FREE"

MORE COMPLICATED — AN OBSESSIVE COMMITMENT TO SCIENCE CAN HAVE DREADFUL CONSEQUENCES

→ WAR TIME MEDICAL EXPERIMENTS IN FASCIST GERMANY & JAPAN

→ CIA MIND CONTROL EXPERIMENTS AT McGILL

→ A WHOLE SERIES OF CASES OF PEOPLE BEING MISTREATED IN MEDICAL EXPERIMENTS IN 1950s 1960s

ETHICS IS A DIFFICULT AREA → SO FAR WE HAVE FAILED TO AXIOMATIZE ETHICS.

WHAT IS RIGHT & WRONG IS BROADLY AGREED BUT DIFFERENCES "AT THE EDGES"

SOME PEOPLE WOULD CLASS AS UNETHICAL WHICH OTHERS REGARD AS ACCEPTABLE

→ PAINFULL/FATAL EXPERIMENTS ON MAMMALS

→ ANY MILITARY RESEARCH

GOVERNMENTS/UNIVERSITIES TRY TO FILTER OUT UNETHICAL WORK

→ DEPENDS ON CONCENSUS IN AN OPEN DEMOCRATIC SOCIETY.

FRANKLIN'S OPINION → I AGREE

"SCIENCE CAN BE USED FOR GOOD OR EVIL. ON BALANCE, IT HAS BENEFITED US MATERIALLY → AND TAUGHT US HOW TO THINK STRAIGHT

BE GRATEFUL AND GIVE SCIENCE MORE MONEY"