Introduction to Particle Physics
(for non physics students)
Angels and Demons is fiction. 

What are the facts?
Angels and Demons is fiction. What are the facts?
How Old is the Universe?
20.00 Creation Big Bang

05.00 SUN → EARTH 06.00

09.30 Oldest Fossils
09.59;30” First Humanoids
09.59 The Millenium
10.00 NOW

eat; drink; sleep
breakfast; come to lectures
Symmetry when warm (high energy) and structures when cold (low energy).
MATTER

ANTIMATTER
...why didn’t it mutually destruct? 
...why is there anything left?
Matter and the Universe

> 40 orders of magnitude
What is matter made of?
1. Look

Light source

Object

Eye
1. Look

Light source

Object

Eye

Beam

Target

Detector
Catch 22:
There's a limit to what we can see with our eye

Beyond (normal) vision

- Eye Limit: $10^{-4}$
- Bacteria: $10^{-5}$
- Wavelength of Light: $10^{-6-7}$
- Atom: $10^{-10}$
- Nucleus: $10^{-14-15}$
- Quarks and Electrons: $10^{-18}$
- Planck Length $\frac{\sqrt{Gh}}{c^3}$: $10^{-35}$
Catch 22: There's a limit to what we can see with our eye.

To look at smaller things we need to use instruments that can “extend” our vision.

Beyond (normal) vision

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The problem is the wavelength of light compared with the size of what you’re trying to look at.
How to learn what things are made of:

- Look
- Resolution
- Wavelength

How to see small things:

- Light waves
- \( \lambda \rightarrow 10^{-7} \text{ m} \)
- Atom \( 10^{-10} \text{ m} \)

Electron microscope

- Electrons
- \( \lambda = \text{const}/p \)
- Atom
2. Smash

How to learn what things are made of

- Look
- Wavelength

- Smash
- Energy

- Heat
- Temperature
...some definitions for ENERGY. Joules are too big for particle energies.... and 0.0000000000000000001 Joules is too messy.... So we need more Practical Units eV, keV, MeV, GeV and welcome to TeV
...some definitions for **ENERGY**

**Joules** are too big for particle energies....

and

0.0000000000000000001 Joules is too messy....

So we need more **Practical Units**

eV, keV, MeV, GeV and welcome to TeV

![Practical Units Diagram](image-url)
Einstein Energy and $E = mc^2$.

Einstein: $E = mc^2$

Special Relativity

$E^2 = (pc)^2 + (M_0 c^2)^2$

Use units such that $c=1$

$E (\text{GeV or MeV})$

$P (\text{GeV/c or MeV/c})$

$M (\text{GeV/c}^2 \text{ or MeV/c}^2)$

$M_{\text{electron}} = 0.5 \text{ MeV/c}^2$

$M_{\text{proton}} = 938 \text{ MeV/c}^2 \approx 1 \text{ GeV/c}^2$

$M_{\text{top}} = 170 \text{ GeV/c}^2$

Proton diameter = length scale: $10^{-15} \text{ m} = 1 \text{ fermi (femtometer)}$
LOOK or SMASH

Wavelength

and

Energy

profoundly related
LOOK or SMASH

Wavelength

and

Energy

profoundly related
3. Heat

... also profoundly related......
SMASH or HEAT

Energy

and

Temperature
SMASH or HEAT

Energy

and

Temperature

10^{-4} \text{ eV K}^{-1}

1 \text{ eV} \leftrightarrow 10^4 \text{ K}
How to learn what things are made of

Look

Resolution \( \frac{hc}{\lambda} \)

Wavelength \( 10^{-6}\text{ eV m} \)

Smash

Energy \( 1\text{ eV} \leftrightarrow 10^{-6} \)

Heat

Temperature \( 10^{-4}\text{ eV K}^{-1} \)

1 eV \( \leftrightarrow 10^4 \text{ K} \)
Beyond (normal) vision

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The Universe

in

Temperature
Energy and
Time
...and the nature of matter
Particles in Three Minutes

A quick survey of how we got here....

....and where we think we’re going next.
The heart of matter in 1905 (Einstein’s great year)
The heart of matter in 1955 (when CERN began)
Electron and Proton utterly different.

The heart of matter in 1955 (when CERN began)

proton 2000 times heavier

10000 times bigger
1955

FORCES in the atom

**ELECTROMAGNETIC** force binds electrons

**STRONG** force binds nucleus

**WEAK** force = radioactivity
Cosmic Rays had revealed STRANGE particles
1955 CERN accelerators replicate cosmic rays on Earth...

..record the images and reveal the real heart of matter....

.....the beginnings of modern high energy particle physics
The heart of matter in 2005 (and even in 2009 !)
The heart of matter in 2005 (and even in 2009 !)

Electron and quark very similar in Mass, Size, Spin and in how they respond to the FORCES
2009

**ELECTROweak** force binds electrons

**FORCES**

in the atom

**United electroweak/QCD**

**electroweak force = radioactivity**

**Colour QCD** force binds quarks
Symmetry when warm (high energy) and structures when cold (low energy)
FORCES 1955-2005

COLD
Electromagnetic
Weak
Strong

WARM
ElectroWeak
Strong (QCD)

HOT
GrandUnified
Force
Standard Model of Quarks Leptons and forces

= pattern based on mass

“cold” = “low” energy

= below 1 TeV
Standard Model of Quarks Leptons and forces

= pattern based on mass

“cold” = “low” energy

= below 1 TeV

superSymmetry when “warm”

(= high energy > 1 TeV)

Higgs Boson

Supersymmetry

Nature of Reality
A Very Short Introduction

PARTICLE PHYSICS
A Very Short Introduction

Frank Close

OXFORD

The New Cosmic Onion
Quarks and the Nature of the Universe

Frank Close
...and patterns (that change)
No mass. Unified Theory

Standard Model
MASS

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<td>W</td>
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Nuclear Isotopes

Mendelev

Snowflake pattern

TeV $10^6$ K
LHC

GeV

MeV

KeV $10^3$ K

eV $10^4$ K

300 K

meV

3 K

$10^{-9}$ sec

< 100 sec.

300 K yrs

$10^{10}$ yrs

Nucl. BANG

Early uni.

$7 \times 10^4$ BANG

LHC