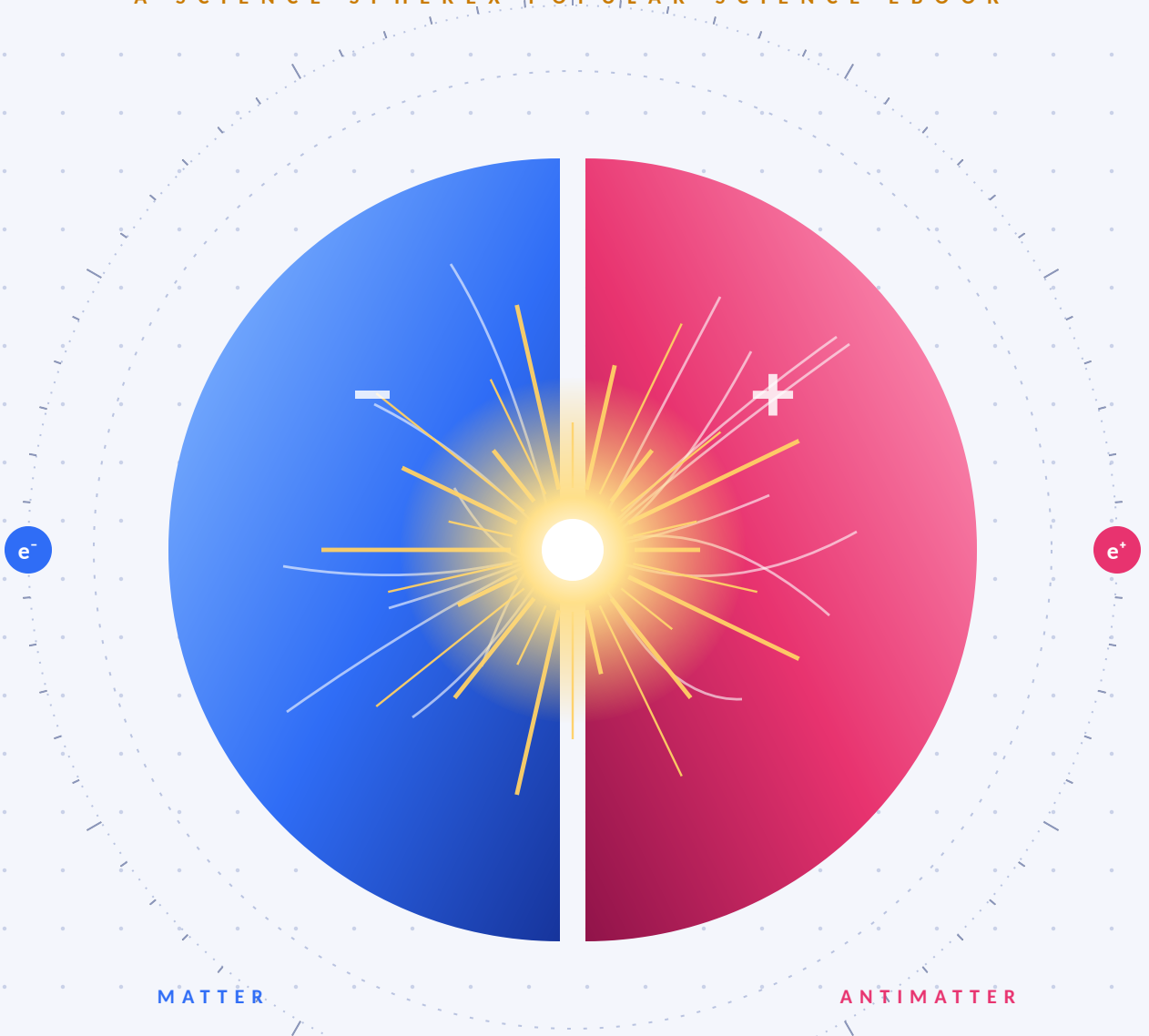


A SCIENCE SPHEREX POPULAR-SCIENCE EBOOK



ANTIMATTER

The Strange Opposite of Our Universe

How Antimatter Works, Why It Exists, What Happens When It Meets Matter, and the Biggest
Mystery in Modern Physics

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Four chapters lay the foundations: what antimatter is, how it differs from matter, and the particles you will meet again and again.

CHAPTER 01

What Is Antimatter?

The mirror image of the particles that make you

ESTABLISHED FACT

Every particle in your body has a twin you have never met. It weighs exactly the same, yet carries the opposite electric charge, and if the two ever touch, both vanish in a flash of energy. That twin is an **antiparticle**, and a collection of them is **antimatter**. It is not a fantasy: hospitals use it every day, and CERN makes it by the thousands.

The word sounds like science fiction, yet antimatter is not exotic in the way a ghost or a wormhole is. It obeys the same laws of physics as ordinary matter. It has positive mass, it has energy, and it is attracted by gravity (as we will see in Chapter 14). What makes it special is what happens when it meets its twin: the pair **annihilates**, and their combined rest energy is released as other particles, often as gamma rays.

Antimatter is real, rare, and useful

Antimatter is not hypothetical. Hospitals use positrons (anti-electrons) every day in PET scanners. Physicists at CERN make antiprotons and antihydrogen atoms and measure them with extraordinary precision. Cosmic rays deliver a trickle of antiparticles to Earth. But our universe contains overwhelmingly more matter than antimatter, and nobody yet knows why. That mystery drives much of this book.

LABEL USED IN THIS BOOK	WHAT IT MEANS	EXAMPLE
ESTABLISHED FACT	Confirmed by repeated, published experiments	Positrons exist; antihydrogen was trapped
THEORY	Supported by theory but not yet confirmed	Specific mechanisms for the matter surplus
OPEN QUESTION	A real, unresolved scientific question	Why is there more matter than antimatter?
SCIENCE FICTION	Fiction or far-future speculation	Warp drives, antimatter 'bombs' as in novels

The signature behaviour of antimatter: what happens when it meets ordinary matter, and how to count the energy.

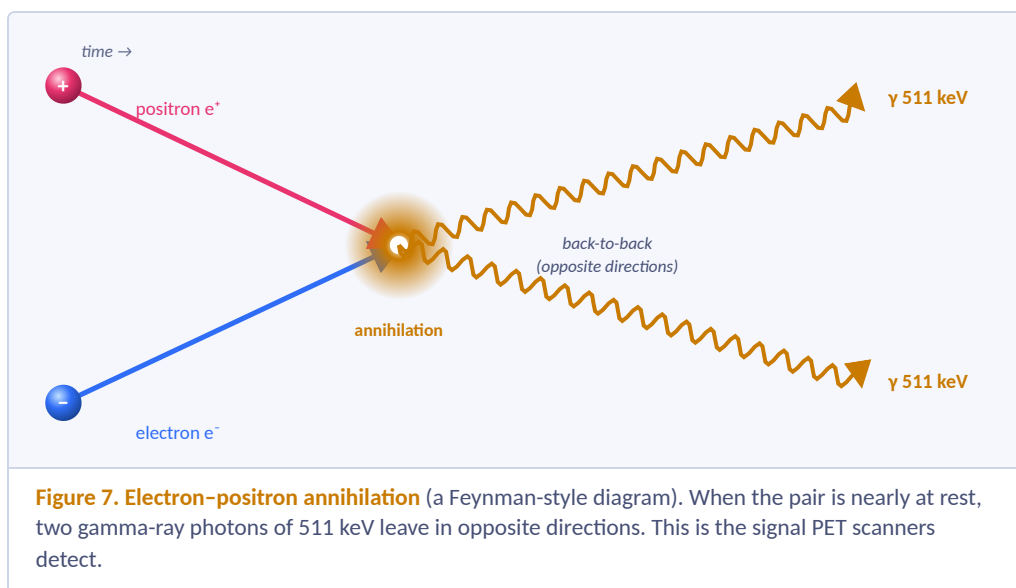
CHAPTER 07

What Happens When Matter Meets Antimatter?

Why the meeting is the whole point

ESTABLISHED FACT

What actually happens when matter meets antimatter? Not a mysterious explosion, but a precise, countable event: the pair disappears, and exactly as much energy, momentum and charge as went in comes out again as other particles.



Why two photons?

If an electron and positron at rest annihilate, the total momentum before is zero. One photon alone would carry momentum, so momentum could not be conserved. At least two photons are needed, flying apart in opposite directions, and each carries 511 keV, the electron's rest energy. Very rarely, three photons appear in a specific state of positronium.

Why Is the Universe Mostly Matter?

The puzzle of the missing antimatter

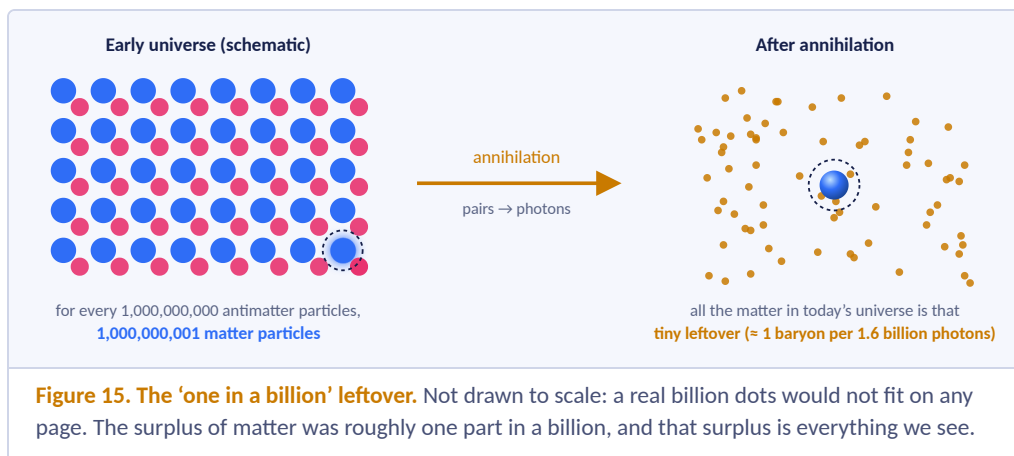
ESTABLISHED FACT

OPEN QUESTION

Everything you can see, from your hand to the farthest galaxy, is made of matter. Yet the laws of physics we know treat matter and antimatter almost identically. This chapter lays out the puzzle: where did all the antimatter go?

Could some galaxies be made of antimatter?

Probably not. A galaxy of antimatter would look just like ours in visible light, but where antimatter regions bordered matter regions, annihilation would produce gamma rays of characteristic energies. Searches for such signals, together with studies of cosmic rays, have found no evidence of large antimatter domains in the observable universe. Experiments such as AMS-02 also search for antihelium nuclei in cosmic rays; a confirmed detection would be momentous, and none has been established.



How big is the imbalance?

Cosmologists measure the ratio of baryons to photons in the universe: about 6×10^{-10} , from observations of the cosmic microwave background and primordial element abundances. Equivalently, there is about one baryon for every 1.6 billion photons. Since photons are the leftovers of annihilation, this suggests that in the early universe, for every billion antiquarks there were about a billion and one quarks.

What antimatter does for us now, what it might do someday, and how much of the popular picture holds up.

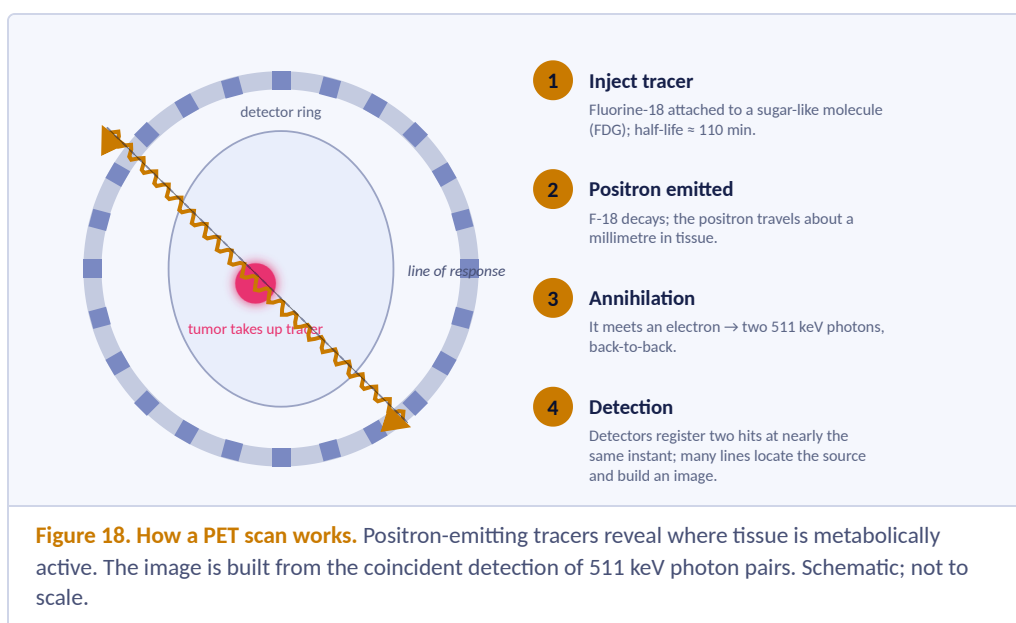
CHAPTER 18

Real Uses of Antimatter, Including PET Scans

From the mirror world to the hospital

ESTABLISHED FACT

Antimatter is not only a puzzle for physicists. Every day, in hospitals around the world, positrons help doctors find cancers, study the brain and track the heart. This is antimatter at work.



How PET works

A radioactive tracer is injected: most often fluorine-18 attached to a glucose-like molecule (FDG). Tumors and active tissues absorb more glucose, so more tracer accumulates there. When F-18 decays it emits a positron, which travels about a millimetre before meeting an electron and annihilating into two 511 keV photons. Detectors around the patient register those photons in coincidence; each pair defines a line, and computers combine millions of lines into a 3-D image.