Matter or Antimatter? Does It Really Matter?

"The seeds of great discoveries are constantly floating around us, but they only take root in minds well prepared to receive them" Joseph Henry

"Quite unforeseen possibilities will unexpectedly spring forth, chances of serendipity which the sagacious can utilize." Walter B. Cannon

"Dans les champs de l'observation, le hasard ne favorise que les esprits preparés." Louis Pasteur

In this philosophical essay I propose to look at an alternative schema in which to describe matter and antimatter. The reason for this is to provide an explanation for the cosmological mystery of the Universe's missing antimatter. In doing so I urge the reader to avoid the inflexible adherence to mainstream concepts. As Walter Cannon[i] once said: "It (the universe) presents all manner of possibilities of novel and unprecedented combinations and readjustments. Consequently, wisdom counsels keeping our minds open and recipient, hospitable to new views and fresh advances. We err if we dismiss the extraordinary aspects of experience as unworthy of attention; they may be the little beginnings of trials leading to unexplored heights of human progress."

In researching antimatter I suggest that the much-revered status of antimatter is misplaced. I believe antimatter is no more special, from the perspective of Physics, than matter. However, by current opinion antimatter is distinguished in a number of ways. For one, it is extremely rare, occurring briefly in cosmic ray events or in highly specialised particle accelerator experiments. Secondly it annihilates with matter to produce prodigious amounts of energy for a given amount of antimatter. Because of the former it took until 1933 before antimatter was first detected and because of the latter it is a very popular energy production mechanism for science fiction space drives.

Matter, by definition, means *'physical substance or objects of a specified kind'*. It is derived from the Latin *materia*[ii], meaning timber. The prefix 'anti' confers the meaning of opposite. The fundamental properties of matter are often expressed as charge, spin and mass. A strict definition of antimatter should thus include the opposite properties. That is antimatter would have the opposite charge and spin to its 'matter' twin but would also have negative mass. Negative mass is a difficult concept that is often associated with antigravity. No known physics experiment to date has ever produced a negative mass that has been measured. I suggest that charge and spin are the only true fundamental properties of matter and that mass, or energy content, is a secondary property. Thus in this context the definition of antimatter should include "same mass, opposite charge and spin." The conventional physics definition of antimatter is that, in reference to a known fundamental particle, it has the same mass but opposite charge. Spin is not included because there is a frame of reference problem in measuring it - that is there is no universal up or down. Some physics textbooks add magnetic moment instead of spin because this can be referenced.

Now let us digress to a time before 1928, to a world where only matter was known. Prior to 1928 no one had publicly expressed the idea of antimatter. It was not an issue in the consciousness of scientists. The matter universe was all there was, disregarding spiritual realms and other religious notions of similar ilk. This changed in 1928 when Cambridge mathematician and physicist Paul Dirac formulated a quantum mechanical wave equation for a relativistic electron in an electromagnetic field. Dirac built his work on the foundations of quantum mechanics laid down some two years earlier by Erwin Schroedinger and Werner Heisenberg.

Dirac's equation was interpreted in a way that predicted electrons could exist in negative energy states. Dirac[iii] further proposed that all negative energy states are occupied. Thus while positive energy electrons are precluded from transitions to negative energy states by Pauli's exclusion principle, it is possible, given enough energy, to remove an electron from the negative energy 'Dirac sea' leaving behind a 'hole'. It is this 'hole' that in 1931 was interpreted by Dirac as being antimatter, as it represents the absence of a particle of negative energy. The 'hole' or anti-electron as it was later called, responds to magnetic and electric fields as though it were a particle of positive charge. Indeed these positive electrons are now called positrons.

In 1932 Carl Anderson of Caltech discovered what appeared to be a positron in a cosmic ray event. Anderson needed to convincingly prove that this particle was not a proton, so he constructed an elaborate cloud chamber between the poles of the world's most powerful electromagnet. In subsequent experiments he was able to prove that the particle was indeed a positron[iv]. Patrick Blackett in the United Kingdom also independently carried out this work in 1933. Thus Dirac had successfully predicted antimatter in 1931 from his mathematical foundations of previous years. It was not long before the existence of an antiproton was hypothesized, but it took another 22 years before the technology was available for antiprotons to be experimentally verified. Thus it seemed that for every elementary particle there existed a corresponding antiparticle, which if it annihilated with its twin particle could lead to the liberation of $2m_oc^2$ of radiation energy.

In 1963 Murray Gell-Mann[v] formulated a new theory of elementary particles that suggested that protons and neutrons are themselves not fundamental, but rather composites made up of three quarks. The two common quarks making up most of today's observable matter are the up quark (u) with a charge of +2/3 and the down quark (d) with a charge of -1/3. Thus a proton is composed of two up's and a down with a total charge of +1, and a neutron is composed of two down's and an up with a net charge of zero. Similarly antimatter quarks were also formulated, with an anti-up (~~u~~) having a charge of -2/3 and an anti-down (~~d~~) having a charge of +1/3. Today it is still considered that quarks represent the truly fundamental layer of matter.

The primary means of forming antimatter in the laboratory is known as pair creation[vi]. This is so named because for every fundamental matter particle created, an equivalent antimatter particle is also created. This occurs without exception, 100% of the time. Thus within particle accelerators matter is created in equal proportions to antimatter, ie 50/50.

One of the biggest cosmological questions is "Where is all the missing antimatter?" In asking this question we are assuming that, in the cosmological laboratory called the

'Big Bang', that matter and antimatter were made in equal proportions. A way out of this, in order to explain observation, is to hypothesize that an asymmetry between matter and antimatter existed with a slight excess towards matter[vii]. All the antimatter then annihilated with the bulk of the matter to form the cosmic background radiation and the small excess of matter formed the universe we observe today.

There is however an alternative theory on antimatter that has never previously been raised. This hypothesis is proposed in order to explain the required 50/50 proportion of matter to antimatter as found in accelerator experiments and as suggested by symmetry theorists. It does not change the standard definition of antimatter but does challenge the frame of reference for the definition of matter. It does assume, however, that there is no hidden property of antimatter such as negative mass, as was previously discussed. The proposal is that the down quarks in protons and neutrons are **re-labeled** to antidown. In this way no physical properties of protons or neutrons are changed. In this scheme a down quark now has a charge of +1/3 while an antidown quark carries a charge of -1/3. Thus a proton will now be composed of two up quarks and an antidown quark and a neutron of two antidown quarks and an up quark. Nothing has changed but a name. The change is, however, very significant and is possible to make only because there is no absolute frame of reference for fundamental matter. Matter as defined today wears only a historical label. When Gell-Mann proposed a new base layer of matter in 1963, it was then that the fundamental definition of matter needed to be reviewed.

The outcome of re-labeling down quarks to antidown quarks is that all positive nuclear particles are now called matter and all negative nuclear particles are called antimatter. By extending this to include leptons it is now possible to have a universe that is 50% matter and 50% antimatter. ie. 50% positive and 50% negative. It means we humans also are 50/50 matter and antimatter. We do not annihilate because our like matter and antimatter particles are not available to do so. That is we do not have the required antiup quarks, down quarks and positrons to create an annihilation scenario.

The argument for re-labeling the down quarks is that we can now explain the 50/50 matter antimatter ratio found in pair creation events without changing any fundamental physical definitions. This argument also reinforces the notion of symmetry, whereby a system is said to possess symmetry if one can make a change in the system such that, after the change, the system appears exactly the same as before. Out of this symmetry comes a new conservation law - the conservation of matter/antimatter ratio. Whenever elementary particles are transformed into other particles via interactions and particle decay, an equal amount of matter and antimatter (defined at the quark level) must also be converted. An example of this is the thermonuclear carbon-carbon cycle that occurs in stars.

The argument for not re-labeling is merely that we keep our historical definition of matter.

If the new quark labels are adopted we are still left with the question of "Where are all the missing antiprotons, antineutrons, etc?" but it is no longer a fundamental problem. Instead we need to explain why nature prefers protons to antiprotons, neutrons to antineutrons, and electrons to positrons. We now can try and explain these matters with antimatter demystified and of the same physical status as matter.

This may lead to a better concept of intrinsic spin or a better understanding of quantum chromodynamics, or an understanding of why parity violations occur. The suggested new conservation law of the matter/antimatter ratio may also lead us to new insights into the structure of leptons when analysing such reactions as the thermonuclear carbon-carbon cycle.

I conclude with another quote from Cannon. "Unless we are willing to weigh novel ideas and methods on their merits and to judge them justly, we may not be participants in momentous decisions, but instead may be worried and unhappy bystanders."

Indeed, if it is true there are no hidden properties of antimatter as we currently accept it, then it is imperative that this alternative hypothesis be put forth for discussion.

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[i] Walter B. Cannon, in the essay "Gains from Serendipity"; *Science Speaks* F.W.Cheshire,
[ii] Concise Oxford Dictionary
[iii] Arthur Beiser, *Concepts of Modern Physics*, McGraw-Hill, Ch.15
[iv] Carl Anderson, The Physical Review 43 (1933): 491-494
[v] Murray Gell-Mann, *The Quark and the Jaguar*, Abacus, 1994, Ch.13
[vi] Paul Davies, *Superforce.*, Penguin, 1995, Ch.1
[vii] Timothy Ferris, *The Whole Shebang.,* Simon & Schuster, 1997, P.325