WHAT'S THE MATTER

Twinkle, twinkle, little star, How I wonder what you are.

Jane Taylor (1806)

I do not believe in atoms.

William Thomson (1862)

"Elementary, my dear Watson, elementary," murmured Psmith.

Pelham Wodehouse (1915)

To a request to explain what an electron really is supposed to be we can only answer, "It is part of the A B C of physics".

Arthur Eddington (1928)

All the known elementary particles … are provisionally described today by a theory that has come to be called the standard model.

Murray Gel-Mann (1960)

During the 1930s, Fritz Zwicky determined that clusters of galaxies have 10 times more mass than their light suggests, and termed the unseen mass "dark matter".

Charles Bennett (2005)

What are tables and chairs made of? To this question, different theories … may propose different answers.

Roderich Tumulka (2006)

It's true. It's Psmith who says it. Holmes never does. My mind wanders. She's been gone for days. He's left to my ministrations. It's four days since I have seen him.

And it's true of matter too. Matter *is* elementary. Well, the stuff we see is elementary. Which is to say, it's made of atoms; each must be one of the elements. In nature there are 92 from H to U.

Atoms are a Greek invention: Democritus, 460 BCE. It's a simple idea and a sexy label. No doubt he hopes I will keep it simple. It's not up to me.

Chemistry is based on atoms. Just as language is on words. But the whole idea of atoms takes a beating lately. Atoms cannot be divided. For two thousand years this is the point of their existence. But recently it turns out that they can. It *was* simple. Now it's not.

The universe has lots of atoms, more than 10^{80} so they say. Some get manipulated. They are much reacted. They are irradiated and decayed. They are ac-

celerated; they are transmuted. The dream of making gold from lead is doable; it just won't pay its way. New elements have been invented. The alchemists are all enthralled.

I paint for him a picture of the atom-smashing era: The atom's very small but by the early 1900s it's clear it *can* be cut. It turns out to have an even smaller nucleus. It's positive. Around it lie electrons like a cloud. They're negative and über small. A little effort peels them off. Atom shattered. Already the idea is in trouble. How much trouble? Well, more atom smashing. It can wait.

We can't see atoms with the naked eye. But high-tech instruments can image single atoms. Then there are the sub-atomic particles. They show up in atom-smashing-type results. We know they come in standard pieces and each has its own place in a list that's called the *Standard Model*.

In the human hunt for nature's secrets, matter is a long obsession. Why does it come in certain forms? Why do they have peculiar properties? Why are they *precisely* what is needed to make books and people who can read them? Today physics answers many questions. But not: What *is* it?

From the dawn of thought the matter matter's one of two top problems. The other is: What makes lights in the night sky move? Today physics sees, or tries to see, these problems as two sides of a single coin. The twin questions of what matter's made of and what makes it move seem to distill to one, a holistic understanding that physicists still struggle to pin down.

Part of the picture is another type of particle. It transmits force. The photon bears the force that affects charged particles such as electrons. There are three others. Two out of three fit neatly in the Standard Model list (the graviton does not).

The Standard Model isn't just a list. It's a stunning achievement. It's based on symmetry and quantum theory. It produces the known particles. It describes their properties. It casts light where all was dark. Particle physics people are, to say the least, enthusiastic. Throwing physics like paint at the quantum wall they came up with the Mona Lisa.

Of course he could find this himself. She's right: It's all there on the Web. But if he looked he'd find I'm keeping something from him. He has this thing: He hates to see the story change. And the tidy matter story I have fed him is about to fall apart.

It goes back to the '30s. Over the years there turn out to be many ways in which the matter that is seen does not add up. Zwicky's first; studying a galaxy, he says most of it must be missing. He calls the stuff he doesn't see *Dark Matter*. Computers calculate there's five times more of it than there is stuff that can be seen. But what *is* this Dark Matter? Well, that's another matter altogether. Maybe

it's black holes. Maybe it's some different kind of particle. What's clear is physicists see little of the total and know nothing about what they do not see. Well, nearly nothing.

They know it isn't made of atoms. They know it isn't giving off its share of light. Thus it is 'dark'. They know too that it's not the only item that is AWOL. It's just the missing mass. There's also lots of missing energy. The reason that it's missing is it too is dark. This can be a bit confusing as mass equals energy. The distinction's made by gravity. *Dark Energy* pays scant attention to the G-field of a galaxy; Dark Matter hangs around.

There is no sexy label for the matter that they see: the mass that's made of atoms and their radiation. But there's now a clear consensus on the numbers:

What they see—4.5%
Dark Matter—22.7%
Dark Energy—72.8%

So what they *don't* see totals nineteen twentieths of all the stuff that's in the universe—or, rather, in the part of it they see. When do I tell him? It will be a nasty revelation: Almost everything's invisible! Even fictional detectives would regard this as bad news. It's evidence gone missing on the grandest scale. The two neat labels, Dark Energy, Dark Matter, are useful like the labels on old maps: *Terra Incognita*, Here Be Dragons. Not.