Name: Period:

Cells (Excerpted and adapted from Bill Bryson's *A Short History of Nearly Everything*

Whatever their size or shape, nearly all your cells are built to fundamentally the same plan: they have an outer casing or membrane, a nucleus in which resides the necessary genetic information to keep you going, and a busy space between the two called the cytoplasm. The membrane is not, as most of us imagine it, a solid, rubbery casing, something that you would need a sharp pin to prick. Rather, it is made up of oily material that has the approximate consistency of a light-grade of machine oil. If that seems surprisingly insubstantial, bear in mind that at the microscopic level things behave differently. To anything on a molecular scale, water becomes a kind of heavy-duty gel, and the cell membrane is like a sheet of iron.

If you could visit a cell, you wouldn't like it. Blown up to a scale at which atoms were about the size of peas, a cell itself would be a sphere roughly half a mile across, and supported by a complex framework of girders called the cytoskeleton. Within it, millions upon millions of objects, some the size of basketballs, others the size of cars, would whiz about like bullets. There wouldn't be a place you could stand without being pummeled thousands of times every second from every direction. Even for its full-time occupants the inside of a cell is a hazardous place. Each strand of DNA is on average attacked or damaged once every 8.4 seconds (ten thousand times in a day) by chemicals and other agents that whack into or it or carelessly slice through it, and each of these wounds must be swiftly stitched up if the cell is not to perish.

The proteins are especially lively, spinning, pulsating, and flying into each other up to a billion times a second. Enzymes, themselves a type of protein, dash everywhere, performing up to a thousand tasks a second. Like greatly speeded up worker ants, they busily build and rebuild molecules, hauling a piece off this one, adding a piece to that one. Some monitor passing proteins and mark with a chemical those that are damaged or flawed. Once so selected, the doomed proteins proceed to a special organelle where they are stripped down and their components used to build new proteins. Some types of protein exist for less than half an hour; others survive for weeks. But all lead existences that are inconceivably frenzied. As one Nobel-prize winning cell-biologist noted "The molecular world must necessarily remain entirely beyond the powers of our imagination owing to the incredible speed with which things happen in it."

But slow things down, to a speed at which the interactions can be observed, and things don't seem quite so unnerving. You can see that a cell is just millions of objects-organelles and proteins of every size and shape-bumping into millions of other objects and performing mundane tasks: extracting energy from nutrients, assembling structures, getting rid of waste, warding off intruders, sending and receiving messages, making repairs. Typically a cell will contain some 20,000 different types of protein, and of these about 2,000 types will each be represented by at least 50,000 molecules. "This means," "that even if we count only those molecules present in amounts of more than 50,000 each, the total is still a very minimum of 100 million protein molecules in each cell. Such a staggering figure gives some idea of the swarming immensity of biochemical activity within us."

What is perhaps most remarkable is that it is all just random frantic action, a sequence of endless encounters directed by nothing more than elemental rules of attraction and repulsion. There is clearly no thinking presence behind any of the actions of the cells. It all just happens, smoothly and repeatedly and so reliably that seldom are we even conscious of it, yet somehow all this produces not just order within the cell but a perfect harmony right across the organism. In ways that we have barely begun to understand, trillions upon trillions of automatic chemical reactions add up to a mobile, thinking, decision-making you (or a rather less reflective but still incredibly organized dung beetle). Every living thing, never forget, is a wonder of atomic engineering.

When cells are no longer needed, they die, with what can only be called great dignity. They take down all the struts and buttresses that hold them together and quietly devour their component parts. The process is known as *apoptosis* or programmed cell death. Every day billions of your cells die for your benefit, and billions of others clean up the mess. Cells can also die violently–for instance, when infected by viruses–but mostly they die because they are told to. Indeed, if not told to live–if not given some kind of active instruction from another cell, Name: Period:

cells automatically kill themselves. Cells need a lot of reassurance.

When, as occasionally happens, a cell fails to expire in the prescribed manner, but rather begins to divide and reproduce wildly, we call the result cancer. Cancer cells are really just confused cells. Cells make this mistake fairly regularly, but the body has elaborate mechanisms for dealing with it. It is only very rarely that the process spirals out of control. On average, humans suffer one fatal malignancy for each 100 million billion cell divisions. Cancer is bad luck in every possible sense of the term.

The wonder of cells is not that things occasionally go wrong, but that they manage everything so smoothly for decades at a stretch. They do so by constantly sending and monitoring streams of messages from all around the body: instructions, questions, corrections, requests for assistance, updates, notices to divide or expire. Most of these signals arrive by means of molecules called hormones, which include insulin, adrenaline, estrogen, and testosterone. These hormones bring information from remote outposts like the thyroid and endocrine glands. Still other messages arrive by telegraph from the brain through nerve cells. Finally, cells communicate directly with their neighbors to make sure their actions are coordinated.

Some organisms that we think of as primitive enjoy a level of cellular organization that makes our own look carelessly pedestrian. Disassemble the cells of a sponge (by passing them through a sieve, for instance), then dump them into a solution, and they will find their way back together and build themselves into a sponge again. You can do this to them over and over, and they will doggedly reassemble because, like you and me and every other living thing, they have one overwhelming impulse: to continue to be.

And that's because of a curious, determined, molecule that is itself not alive and for the most part doesn't do anything at all. We call it DNA, a molecule of supreme importance in biology, which we will address at a future time.

SUMMARY (10 – 15 key points, interesting facts, etc.)
