Ten Trillion Cells Walked Into a Bar

A humourous and unusual perspective on how, exactly, a person is even able to stand up, let alone walk into a bar

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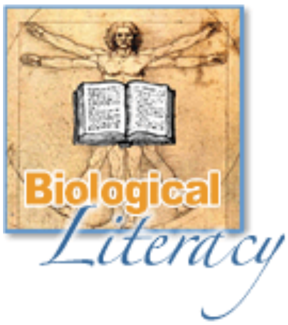
by Paul Ingraham bio



Articles in the Biological Literacy series are fun explorations of how the human body works. See below for a complete listing of articles in the series.

You are a colony of (at least) ten trillion cells, both your own cells and stupefying numbers of guests. [1] That is what a human being is — a very large social gathering of cells. Ten trillion is a conservative estimate, but it is one heck of a lot of cells. That is about 200,000 times more cells in a single person than there are people on planet Earth. That's the sort of number that you really can't get your head around. Even if you have a very big head.

> *We are, each of us, a multitude. Within us is a little universe.*
>
> *Carl Sagan*

So how do ten trillion cells walk into a bar?

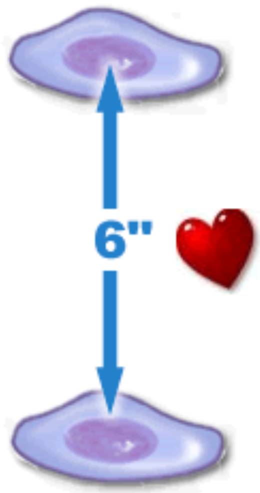
How do they walk, I mean? Or even stand up? It's a bit of a trick for ten trillion cells to do that. Individually, they certainly couldn't pull it off. A single cell would have trouble walking a centimetre for a hot date with another single cell. [2]

It's a co-operative effort, obviously. There are probably many committees, subcommittees and review panels involved. But, in spite of the biological bureaucracy, the end product — walking — is quite efficient. Walking is so efficient, in fact, that is constitutes one of the great mysteries of how people work. We [3] still can't make a bipedal robot that can walk, not like us anyway. We humans simply don't understand the details of our own locomotion.

> *Rocket science isn't all that difficult. It's not brain surgery.*

a rocket scientist

But we do have some idea how we at least stay upright. Even I understand it. This superficially simple thing of rising up to a height of six feet or more is an impressive feat for a bunch of cells who are, individually, shorter than a coffee stain. But together they pull it off, and that basic accomplishment is what I'll focus on here. This is stuff that cells probably learn in cell kindergarten.



Not to scale

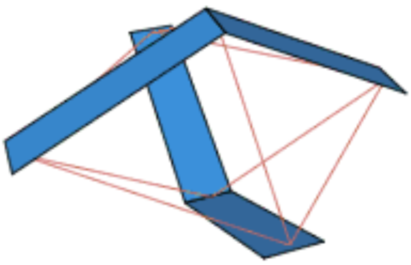
You aren't stacked

Contrary to popular opinion, bones are not really stacked on each other like bricks. We do not really rest on our joints as much as you might think, nor in the *way* you might think. There is compression and friction in joints due to gravity, but this is not the supportive principle by which we manage to get upright each morning and stay that way.

Vertebrae in particular are not really made for "support." We are one of the few creatures on Earth with an upright spine, the odd animal out; all other vertebrates on Earth have a *horizontal* spine, which is much more obviously not built for bearing weight by stacking. In fact, the spine we have is really not particularly well-constructed for verticality. It's as though we borrowed a tool used by other species for hammering nails, and decided, "Let's use this for screwing in lightbulbs." It's a bit queer, really. [4]

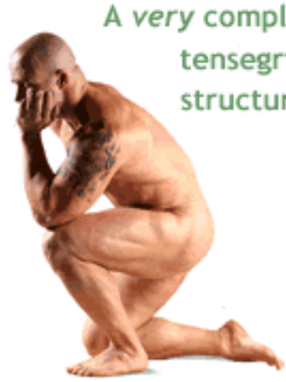
In fact, rather than being stacked, we are held together and upright by muscles. Bare skeletons, as a general rule, fall over very easily. In the living body, even when we think that we are completely relaxed, our muscles are actually sustaining a constant level of tension — called "resting tone" — that holds joints together. [5] When we are anaesthetized, surgeons must be cautious not to dislocate joints, [6] because they become quite loose. This constant tension is what we really "stand on" — not bone resting on bone.

This idea, in which the rigid elements of a system "float" in a continuous tension network, was called "tensegrity" (tension/integrity) by Buckminster Fuller. For a long time the ideas were more widely known among architects than biologists. [7] Biotensegrity could seem like quite a flaky concept at first glance, and the idea has certainly been co-opted for dubious purposes over the years, [8] but "tensegrity biomechanics" and "biotensegrity" are slowly coming into their own as an important way of modelling and explaining biomechanical function.



A simple tensegrity structure

A more complex tensegrity structure



A *very* complex tensegrity structure!

Bones float in muscle, functioning more like "spacers" than bricks. They provide rigidity for leverage and as foundations for complex arrangements of high-tension wires (muscles and tendons). We are pulled upright, and held upright, in much the same way a circus tent pole is erected and held upright — not because it is resting on itself, but because it is being pulled equally in all directions by ropes. Unlike a circus tent pole, we actually need to move around, so this arrangement is extremely dynamic and active, constantly at work even when we are sitting.

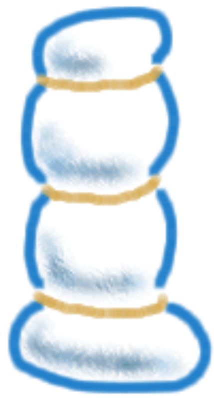
There is one other major principle that keeps us upright: hydrostatic pressure ("hydrostatic" meaning "latin for something").

We are "bags of mostly water"

Once again, bones are of secondary importance to another more important substance: soft connective tissue. Some aliens on *Star Trek: The Next Generation* referred to humans as "ugly bags of mostly water." [9] And right they were, at least about the bags and the water. Ugly depends on which bag of water we're talking about (but let's not go there).

The point the aliens were trying to make was that humans are mostly water — and everyone knows that, right? More specifically, and less widely known, is that our water is contained in flexible membranes. A bag. The "sack" is made of our connective tissue, intricate layers of a substance somewhat like Saran Wrap that literally holds us together. We have more connective tissue than anything else. [10]

The water (hydro) inside of us is under constant (static) pressure — hydrostatic pressure. The bag is tight. This is just like putting a tight elastic band around a water balloon: it squishes it into a more elongated shape. If you were to put several rubber bands in a row around a water balloon, it would start to look more like a tube than a balloon. In fact, it might start to resemble, say, a leg. If only it could balance, this "balloon leg" could stand upright — thanks to the pressure of the water inside.



A balloon held upright by hydrostatic pressure created by elastic bands

The balloon analogy is surprisingly apt, because our anatomy actually is subdivided into balloon like subdivisions defined by thin, tough layers of Saran-wrap like tissue called "fascia" — same stuff as the gristle in steak. The compartments can swell even like a balloon (which can be quite disastrous). [11] An even better analogy is that these are like sausage wrappings, giving the loose contents shape and firmness.

This is entirely how plants stand up. Spinach has no spine, no bones at all, but it still manages to stand up. Unless you don't water it, and then it wilts — no water, no pressure, no standing up. Speaking of sausages, of course there is one part of the human body, the male human body specifically, that illustrates this principle *perfectly*.

Ta da!

Our ten trillion cells manage to walk into a bar by applying two major physical principles: biotensegrity and hydrostatic pressure. Our cells build tough membranes to tightly surround compartments of pressurized water, they make rigid bones to act as spacers and points of leverage, and they arrange themselves in complex systems of muscle tissue in order to literally "pull" us into the vertical position and keep us there like a tent pole.

How ten trillion cells order a tall cold one and generate bad pick-up lines is a completely different mystery altogether.

Is tensegrity clinically useful?

Not really, no. It's basic biology, fascinating but impractical, at least for therapy. Many massage therapists like to believe it is, though, and the idea of tensegrity is particularly beloved by massage therapists who are keen on fascia (the stuff mentioned a few paragraphs back), and there are a *lot* of those, and they are *very* keen on fascia. [12] The "logic" goes something like this:

- tensegrity is an important and nifty principle in biomechanics, and fascia is important working part of tensegrity
- fascia can be pulled on by a therapist
- therefore, pulling on fascia is biomechanically important

That's about all there is to it (so, not much, in case my sarcasm wasn't clear). Here's an amusing example of this sloppyness: a bit of junky science published in the *Journal of Manipulative & Physiological Therapeutics* in 2013, a study that compares two kinds of massage for shoulder pain, regular Swedish versus "tensegrity-based" massage. Which I have literally never heard of in 15 years of studying massage (although it's obvious what they think they mean). I smell a pet theory! "Tensegrity-based" massage is not actually a thing. There is no TBM® or standard definition. It means about as much as "anatomy-based." Massage "based on the tensegrity principle" is wide open to interpretation to the point of absurdity. [13]

This is about as legit as "tensegrity-based" therapy science gets.

About Paul Ingraham

I am a science writer, former massage therapist, and assistant editor of ScienceBasedMedicine.org. I have had my

share of injuries and pain challenges as a runner and ultimate player. My wife and I live in downtown Vancouver, Canada. See my full bio and qualifications, or my blog, Writerly. You might run into me on Facebook and Google, but mostly Twitter.

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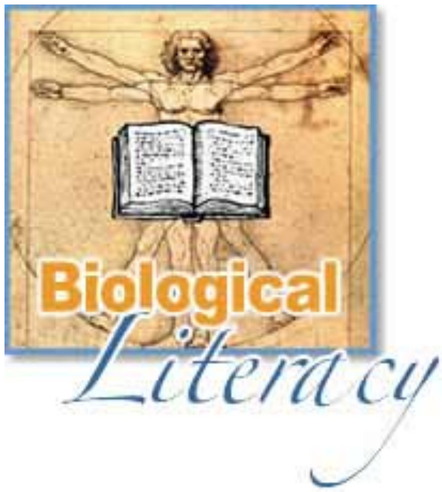

Here are the ten most popular articles on PainScience.com on the theme of health and biological literacy: what I think of as "owner's manual stuff."

- The Unstretchables — Eleven major muscles you can't stretch (no matter how hard you try)
- Organ Health Does Not Depend on Spinal Nerves! — One of the key selling points for chiropractic care is the anatomically impossible premise that your spinal nerve roots are important to your general health
- Dance of the Sarcomeres — A mental picture of muscle knot physiology helps to explain four familiar features of muscle pain
- Why Do We Get Sick? — The connections between poor health and the lives we lead
- Healing Time — Can healing be hurried? Would we even notice if it was?
- We Are Full of Critters — The human body is a colony of ten trillion co-operating cells
- You Might Just Be Weird — The clinical significance of normal — and not so normal — anatomical variations
- From Atoms to Elvis — A wide-angle look at the foundations of biology
- How Many Muscles? — A (slightly tongue-in-cheek) tally of the body's many muscles
- Singing, Breathing, and Scalenes — Connections between singing, breathing and a strange group of muscles
- An Introduction to Health Literacy — Why everyone needs to know more about biology, medicine, and health

Other interesting reading:

- Biotensegrity: A new way of modeling biologic forms (http://www.biotensegrity.com). Dr. Stephen Levin is an orthopedic surgeon with a special interest in tensegrity biomechanics and biotensegrity. His website is a starting place for technical reading about tensegrity, as it has a well-annotated page of links. There is much of interest here for the true therapy geek. For example, Levin discusses the role of muscle tension in posture in some detail: Muscles at Rest. The history page is a good introduction to the site.

Notes

1. The ten trillion number is in the middle of a wide range of possibilities suggested by experts over the last century. The highest estimate I've ever seen, published in 2003 in the popular book *A Short History of Nearly Everything*, by Bill Bryson, was in the quadrillions — that's right, *quadrillions*, as in thousands of trillions! (And that is probably wrong.) In 2006 in National Geographic, citing various experts, Joel Achenbach reported the popular myth that the microbes living in our bodies outnumber our own cells by the crazy ratio of 10 to 1, and there are a hundred trillion microorganisms in the intestines alone — so those figures would also put the total for the whole organism well into the quadrillions. In fact, our bacterial passengers probably do not outnumber our own cells by anywhere near that much, and almost all of them are in the poop chute, as opposed to a widespread population of symbiotes: see Scientists bust myth that our bodies have more bacteria than human cells.

   At the other estimating extreme, some estimates of the number of cells we have go as low as tens of billions. But, regardless, we have a *lot* of cells!

2. If you do the math, "walking" a centimetre for a cell is like us walking about a kilometre — not too far for a hot date.

3. "We" meaning "geniuses at MIT studying robotics." And "the Japanese."

4. For a rather more detailed exploration the oddities of spines and their unsuitabability for verticality, see: Natural Imperfection: Evolution doesn't care if you have back pain … just as long as you can breed

5. There is just one joint in the body that can maintain its integrity after complete muscular dissection: the hip joint. The socket of that joint is so deep and perfectly fitted to the ball of the femur, and the capsule of ligaments around it so sturdy and air tight, that it is held nicely in place by "suction." However, cut a tiny hole in the capsule with a scalpel, and the joint immediately dislocates!

6. Casey AT, O'Brien M, Kumar V. Don't twist my child's head off: iatrogenic cervical dislocation. *BMJ*. 1995 Nov 4;311(7014). PainSci #57060.

   From the article: "… extreme care must be taken in the positioning of the anaesthetised and paralysed child where the normal protection from cervical musculature is lost: extremes of neck rotation in children are dangerous."

7. Tensegrity. Wikipedia.com.

8. Carlos Castaneda abused "tensegrity" thoroughly, and Dr. Levin writes that he has "moved to the term 'biotensegrity' to try and clearly distinguish what is science and what is 'new wave mysticism' in regards to biologic structures." Also, many therapists claim that tensegrity has significant clinical implications, which is quite a pretentious reach, and one of the best examples of making too much out of basic biology. For instance, tensegrity comes up routinely as a vague justification for manipulating fascia. Biotensegrity is nifty biology, but it has about as much to do with hands-on therapy as quantum physics does.

9. Sabaroff, Robert *et al.* and *ibid* and *lorem ipsum*. "Home Soil," *Star Trek: The Next Generation*, Episode #18, Season 1, Original air date: February 22, 1988. Paramount Television. I also have *an entire article* about this quote. Seriously. See: Ugly Bags of Mostly Water: The chemical composition of human biology

10. We really do have a lot of connective tissue, but connective tissue also includes some surprising and counterintuitive tissues like blood and fat.

11. A gory example is available in the free introduction to my shin splints tutorial. Just scroll down until you find a freaky picture of a dude's messed up leg.

12. Ingraham. Does Fascia Matter? A detailed critical analysis of the clinical relevance of fascia science and fascia properties. PainScience.com. 14343 words. Many massage therapists are selling "fascial therapy" to patients. The main idea is that fascia — sheets of tough connective tissue found throughout the body — can get tight and restricting, and needs to be "released" by pulling on it. Fascia science is considered an exciting frontier in manual therapy. Unfortunately, although some fascia biology is interesting, the stuff does not seem to have any properties that are actually relevant to healing and therapy. Key examples of fascia research either fail to support fascial therapy or actually undermine it. Enthusiasm about fascia seems to be an unjustified fad.

13. Kassolik K, Andrzejewski W, Brzozowski M, *et al.* Comparison of Massage Based on the Tensegrity Principle and Classic Massage in Treating Chronic Shoulder Pain. *J Manipulative Physiol Ther*. 2013 Jul. PubMed #23891481. The defining characteristic of tensegrity-based treatment offered in the abstract of this paper is merely *where* massage was applied (not how): "directing treatment to the painful area and the tissues … that structurally support the painful area." As opposed to foot massage, perhaps? Meanwhile, the control group massaged "tissues surrounding the glenohumeral joint." So, shoulder massage compared to … shoulder massage. This comparison may be about as meaningful as a taste-test of tomatoes and tomahtoes. Giving these researchers a little benefit of the doubt, perhaps they were trying to describe the size of the treated area, also known as "less thorough" and "more thorough." That would be a somewhat interesting comparison, though not really useful for validating a treatment idea as vague as "tensegrity-based massage." I can think of a few (about 17) non-tensegrity-based reasons why more thorough massage might work well. "Be thorough" is pretty much the first lesson in massage school. The shocking conclusion? They found that "more thorough" worked much better.