8 Spirals

The results suggest a helical structure (which must be very closely packed)...

Rosalind Franklin, 1952, describing Photo 51 (Fig. 8.1), taken by her assistant, Raymond Gosling, which evidenced the helical structure of DNA.

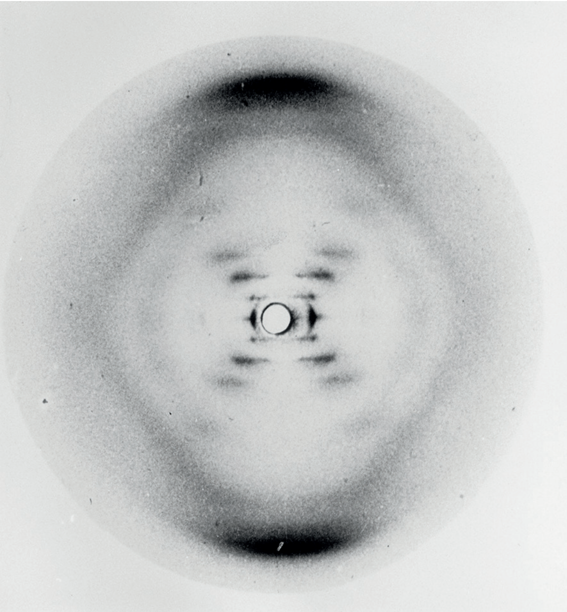


Figure 8.1
Photo 51, an image of the double helix structure of a DNA molecule taken in 1952 by Raymond Gosling while working under the direction of Rosalind Franklin by using X-ray crystallography (considered by some to be the most important photo ever taken), led directly to Watson, Crick and Wilkins being awarded the Nobel Prize.
(Used with kind permission from the King's College London Archives.)

Life is helical.

Once you begin to tune in to nature's winding whorls, you will see them everywhere. Some are more easily seen, such as in the nautilus shell or sunflower, others are more hidden, as in our muscle fibers and DNA, but from viruses to vertebrates, all of life is helical.

Why are spirals such ubiquitous structural patterns? Spirals emerge naturally when many of nature's basic shapes come together. When you observe spirals in the world, you become more mindful of them. When you actually draw and build them, you get a more visceral understanding of how spiralic structures manifest when materials arrange themselves, and for nature's helical force management strategies. This tactile awareness of helical patterns can help us awaken to the spirals in the body, the helicity of our own internal workings.

Spirals in the natural world

In nature, spirals abound. We can see them in sunflowers, seashells, ferns, cacti, and there is even a group of animals called spiralia. Even beyond the world of living organisms, they are all around us, manifesting spontaneously as forces interact with matter. Lift a stopper in a sink full of water, and you are introducing energy (in the form of added gravitational pull) into the system. As gravity pulls the water down the drain, the water follows the path of least resistance, and it turns out this is not a straight line at all. Responding by organizing itself into a minimal energy configuration, the water creates the vortex that results. In rivers, hurricanes, ocean currents, and even in the Milky Way that dwarfs our home planet, this spiraling is happening all around us. These spirals are emergent properties that result from structures (atoms, molecules, stars…) coming together and the material *organizing itself* into helical, minimal energy configurations in response (Fig. 8.2).

Experiential: Observing spiraling in nature

Observe water going down a drain, then look at some of the other spirals in the natural world. Find the spirals in both non-living structures and in living organisms. Note that some are more actively dynamic (weather systems, liquid pouring out of a bottle) and others are more structurally stable (shells, ferns), but this is, at least in part, a matter of time scale. Is the Milky Way a dynamic system? Absolutely! And yet, it also seems quite stable, at least for the next couple of thousand millennia.

Chapter 8

Figure 8.2
Spirals are ubiquitous in nature at all scale levels, and can be seen here in: (**A**) a rose of interacting galaxies; (**B**) a cactus; (**C**) Jupiter's south pole cyclones; (**D**) a snail; (**E**) a vine; (**F**) the horns of a ram in Skye, UK.
(A, Image courtesy of NASA, ESA, and the Hubble Heritage Team (STScI/AURA); C, Image courtesy of NASA's Jet Propulsion Lab NASA/JPL and Caltech/SwRI/ASI/INAF/JIRAM; D, Photo by Skitterphoto from Pexels; E, Photo by Tim Mossholder on Unsplash; F, Photo by Livin4wheel on Unsplash.)

Spirals

Vines, roots, and shoots

Knowing that nature makes wide use of spirals, imagine how a spiraling action could help a root drill its way through the Earth. We can observe helical growth patterns in vines and in the shoots of new sprouting plants. Consider a vine whose leading shoot has a twining tip reaching out like a hand to grasp. It may seem more efficient to reach out in a straight line, but although this would allow the quickest touch per centimeter of growth, of what use would that touch be? The spiraling structure of the vine tip may require more organismic effort in terms of material generated, but the payoff for that extra effort gives the delicate vine tip the mechanical advantage of being able to hook onto almost anything that a gentle breeze allows it to encounter, catching what it can to pull itself up and wind itself around, and so allows it to climb. Although a straight line seems most efficient, for many actions a curving line is called for because it is functionally more useful. At the molecular level and in the biotensegrity model, just as in a soap bubble, curved lines are actually made of much smaller straight lines beyond the level that we can see.

Experiential: Helical vine tips and tree roots

Imagine you are standing like a tree, extending and growing your roots down into the Earth in your quest for nourishment. Your root tip suddenly meets with a rock. What do you do? Do you give up? No. You respond to the obstruction by reconfiguring and changing direction. Gently but steadfastly persevering, your root tip must take a turn to achieve its ideal path.

Next, stand near a wall that has a window frame or door frame. Place a fingertip on the wall and close your eyes. Imagine your fingertip to be a root tip growing along and following the wall. When you come to the door or window frame, feel the interruption in your path. Allow your fingertip root tip to rotate and roll just a bit, just enough, this way and that, so that it can wind and find its way around.

When you turn, what do you feel? Is this a local movement or a global movement? Feel what's involved in the action as the body generates a helical movement response. Notice how you can use the frame, the obstruction itself, to provide the counterforce and the guidance needed to adjust your angle and direction just enough to turn. When your root tip turns, feel how everything behind it is also part of the turning.

A related and useful project is to simply sprout a few seeds and observe the spiraling root tips and shoots as they emerge.

Spirals in our tensegrities

Our six-strut tensegrities have inherently helical structures, and will expand or compress spirally. It may be easier to feel this than to see it. In a way very similar to the VE, this spiraling quality is yet another emergent property of the six-strut tensegrity. As it compresses inward and expands out (as discussed last chapter as part of the VE path) it is simultaneously moving around in a spiral path. Fuller called this "*in-out-and-around*" movement (1975), and Martin writes of how, for organisms, "there is only one basic movement, the complex 'in-out-and-around' motion" of Fuller (2016, p. 75). Martin further agrees that Avison's tensegrally informed term "biomotion," (as a replacement for the anachronistic "biomechanics"), succinctly expresses the "in-out-and-around" movement of living beings, and we use it here accordingly and with Avison's kind permission.

Experiential: Feeling the spiraling in your tensegrity

To feel the helical expansion and compression of your six-strut tensegrity, place it between your two hands, with opposing cable triangles against your palms. As you push your hands together, try to feel the helical action of the tensegrity structure. You can also feel the spiraling action by placing a cable triangle side of your tensegrity on a table, and placing your palm on the top (which will also be a cable triangle). Notice how the six-strut tensegrity, when pushed or pulled, moves through a part of the same transformational path as the VE.

Chapter 8

Spirals in human invention

We humans discovered long ago that spirals can help us get work done more easily and efficiently. Consider the advantages and usefulness of spirals in human inventions such as springs, screws, bolts, corkscrews, drills, spiral staircases, spiral bound notebooks, Tesla coils, and drain snakes. Archimedes invented a water screw that, when turned, would carry water from a lower level to a higher one (Fig. 8.3).

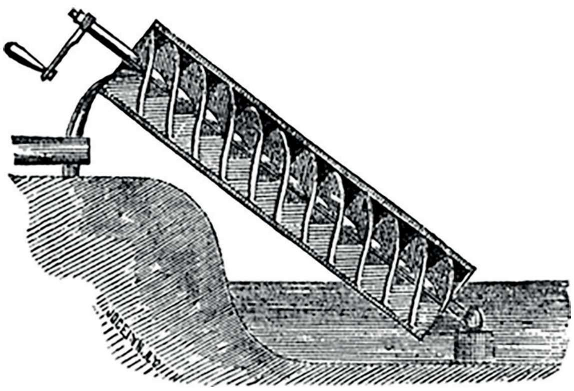


Figure 8.3
Archimedes' screw.

Getting a feel for spirals

The VE in the International Mathematical Union video clip (Link 7.3) referenced in the last chapter shows how golden rectangles emerge from within the tensegrity icosahedron. Golden rectangles have proportions related to the golden ratio, and something called the Fibonacci number sequence, named after its mathematician discoverer, who was also known as Leonardo of Pisa. This well is too deep for this book, but here we want to emphasize the importance of the Fibonacci number sequence and spiral, as they show up often in nature (snail shells, flowers, pinecones). Fibonacci was born in 1175, just two years after construction began on the now-famous Leaning Tower in his hometown. The Fibonacci sequence is an addition pattern where each new number is generated by adding the two numbers that came before it. By extension, the sequence generates golden rectangles and Fibonacci spirals.

Experiential: Drawing Fibonacci spirals

Making a pattern of progressively larger squares by following the Fibonacci number pattern allows you to create your own Fibonacci spiral (Fig. 8.4). To start, use graph paper if possible, as this makes the process quick and easy. The number sequence begins with 1, 1, 2, 3, 5, 8…and so on.

Make a small square on your paper. Its dimensions will be considered to be one unit in length and width. Draw a second square of the same size alongside it, such that the squares share a common side. The first two numbers in the Fibonacci sequence are 1 and 1; the two squares represent these first two numbers (as each is one unit square).

Since $1 + 1 = 2$, the next number in the sequence is 2. Using one of the 2-unit lines already drawn in linking the two previous squares as a starting point, draw a square that is 2 units square on each side (see images). The larger, 2×3 rectangle you now have is your first golden rectangle.

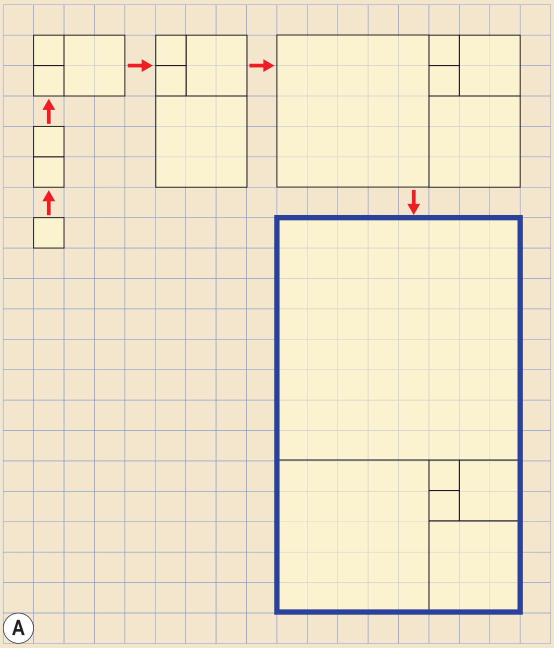
A square with sides of length 3 will be next, drawn up against the long side of the rectangle you have just created, which is length 3. This creates a new rectangle of dimensions 3×5 ($3 + 2 = 5$, the next Fibonacci number in the sequence), to which you will next add a square with length 5 sides, using one of the length 5 sides you have already created.

This pattern repeats, adding squares of 8, 13 and 21 as space on your paper permits.

Lowell_Everything Moves.indb 134 20/08/20 5:05 PM

Once your paper is filled with progressively larger and larger golden rectangles, it is time to draw your Fibonacci spiral. Start in the first square you drew, in the corner where the squares of unit sizes 1, 2, and 3 meet. Draw a spiral outward, following along from the corners of one square to the next (Fig. 8.4B).

If you want to keep going, watch the episode of Vi Hart's *Doodling in Math Class* on Fibonacci, available widely online (Link 8.1).



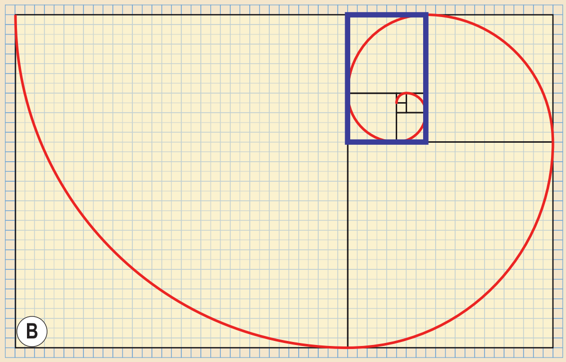


Figure 8.4
Drawing a Fibonacci spiral. The size of these squares will vary depending on the size of the sheet of paper you are using for this exercise, and the size of the squares on the paper. For example, your final and largest square could be 8 x 8, as in Figure 8.4A, or may be larger, such as with the 34 x 34 square in Figure 8.4B. In any case, it will always involve numbers from the Fibonacci sequence: 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, etc.

How spirals emerge from tetrahedrons

Just as spirals can emerge from a sequence of number patterns, spiraling structures naturally emerge when tetrahedrons are connected face to face. Fuller called these "tetrahelices" (tetrahedral helices) (Fig. 8.5), and not just one, but six spirals will naturally emerge in them, with some running clockwise, others counterclockwise, some spirals tighter, and others looser: spirals within spirals. Linking tensegrity icosahedrons will also naturally generate several different helices, and all of these helices follow the same laws of close packing and minimal energy we have already been investigating (Scarr 2018, p. 62). We can begin to see how a variety of shape and structures can emerge when these helices come together.

My first tetrahelix

At some point in my study of biotensegrity, I realized I had never actually made a tetrahelix. I got out my toothpicks and marshmallows and did some research to find a formula for the pattern to build one. Having no luck with that, I tried to work it out for myself.

I put two tetrahedrons together, and realized that there is only one possible configuration for doing this (try it and see). Then I put three tetrahedrons together; there was only one possible way to do that as well (however you build it, you will end up with the same shape). When I started to add a fourth tetrahedron, things changed. There were now at least three different shape options available. I couldn't figure out which one was right, and nothing I did seemed

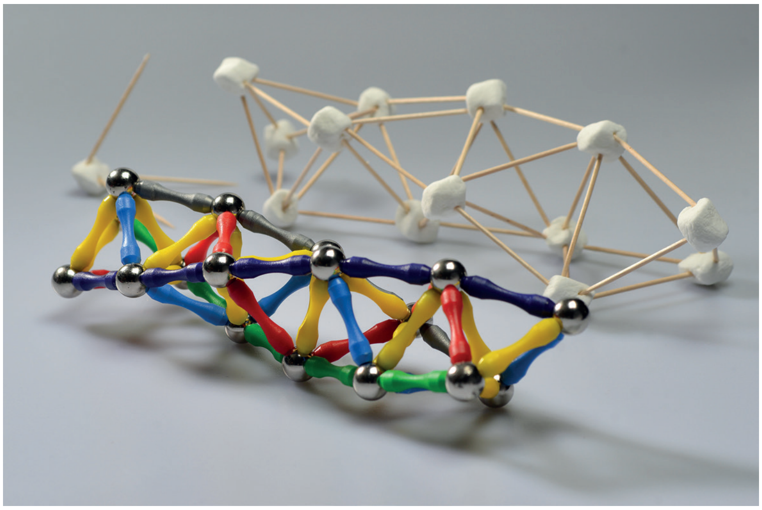


Figure 8.5
Tetrahelices are linked tetrahedrons. A left- or right-dominant spiral pattern naturally emerges. Closer examination reveals six interpenetrating spirals of both directions. Here, the three loosest and most external-appearing spirals in the multicolored tetrahelix are silver, purple and green. The tighter red and blue spirals run in the opposite direction. The yellow spiral is the tightest and most internal, and runs in the same direction as the three loosest spirals. The tetrahelix can be lengthened by incrementally adding "sputniks".
(Photos © Ana Teresa Ortega.)

to look helical enough. Frustrated, I decided to let the project go.

After doing some deeper research, I learned that in a tetrahelix, the placement of the next sputnik in terms of rotational orientation never repeats. Ever. Like the number *pi*, it just goes on forever. For this reason it is called *aperiodic*. Perhaps this makes articulating a formula for building a tetrahelix a bit challenging. No wonder I could not find one!

Later that week my grandson was visiting; we sat at the table with the toothpicks and marshmallows and started to stick them together to make different kinds of shapes. Because my attention was mostly on my grandson, I knew I could not focus on making a tetrahelix, so I decided to just relax and play. Soon I had a thought to make a straight line as much as I could with these tetrahedral shapes. Before I knew it, voilà! There in my hand, without planning, the tetrahelix had emerged.

Experiential: Making tetrahelices

You can experience how tetrahelices form by starting with a tetrahedron and continuing to add tetrahedrons by connecting additional sputniks with toothpicks and connectors. First, make a tetrahedron with toothpicks and connectors (as previously shown in Chapter 7, Shape, Space, and Volume), and set it aside. Next, make a *sputnik*. Connect the three free toothpick ends of the *sputnik* to the three connectors on any side of your tetrahedron. You will now have two linked tetrahedrons.

Make another *sputnik* and connect its three free toothpick ends to any side of the (now) double tetrahedron. You now have three linked tetrahedrons. Again, there is only one possible configuration for this, so do not be concerned with which side needs which connection!

Now comes the tricky part. Up until now, it did not matter which side of your structure you chose for attaching the sputnik, but starting now it will.

Look at the three linked tetrahedrons you have and imagine them as being in a slightly crooked line. You can try rolling the structure to see this more easily. You might even notice the beginning of some spirals emerging (there are actually several in a tetrahelix).

Without overthinking things, imagine where you might add a new sputnik if you wanted to keep this line as straight as possible. This is how to find the next face to add to. If you are left handed, you will probably be adding to the left and if right handed, adding to the right.

Each time this positioning will be slightly different, because the position in space of a new tetrahedron will *never* be

exactly in line with any previous tetrahedron (*aperiodicity* is one of the unusual characteristics of a tetrahelix).

Once your tetrahelix is constructed, use paint or markers to find some of the helices contained within and use different colors to distinguish them. Alternatively, used colored magnetic lengths (such as Magz) to create your tetrahelix. Once you see the helical patterns emerge, make each of the six interpenetrating helices a different color (see Fig. 8.5). None of the links, interestingly, does double duty; it will become clear where each of the six interwoven spirals is.

Although the tetrahedron is an ancient, primordial shape, it is interesting to note that the tetrahelix is a relatively new area of study, and it relates to several other fields in which understanding is still in the process of unfolding. The tetrahelix is also known as the BCB helix, after three mathematicians who studied it independently and almost concurrently in the last century (it is also sometimes called the Boerdijk–Coxeter helix). Arie Hendrik Boerdijk began studying it in 1952, investigating the close packing of spheres while working for Philips Research in the Netherlands. Harold Scott MacDonald Coxeter, known as "the man who saved geometry," was a friend of R Buckminster Fuller and MC Escher, and influenced them both. John Desmond Bernal studied the close packing of spheres in order to better understand liquids and the fluidic tissues of biology. It is of note that the study of biotensegrity involves all of the above components: spherical close packing, the perspectives of R Buckminster Fuller, and soft matter fluidic biologic tissues.

The meeting of the ancient and the modern come up repeatedly in the study of biotensegrity. The tetrahelix influenced architect Arata Isozaki's design of the stunning Art Tower Mito in Mito, Ibaraki, Japan (Fig. 8.6). Helices that arise from closely packed structures (as tetrahelices do) connect with fields that may seemingly be otherwise unrelated, but which are increasingly becoming relevant to biology, including the study of quasicrystals, soft matter and weaving. Weaving is ancient, but only forty years ago quasicrystals were thought to be structurally impossible. Since the discovery of quasicrystals in the early 1980s, they have been found in meteorites, and biological quasicrystal structures have been investigated in collagen, neurotransmitter receptors and microtubules (so they have actually been around for millions of years). Again we can see how, for those wanting to delve more deeply into biotensegrity, there are many possible branches to follow.

Figure 8.6
Art tower Mito in Mito, Ibaraki, Japan, by architect Arata Isozaki, is based on the tetrahelix.
(Photo by CyberOyaki; CC by 3.0.)

Spirals are a part of the way nature puts things together. They are also part of the way we put ourselves together, starting from before cell one, and continuing through-

out our entire lives. Our movement is a product of, and dependent on, our helical structure.

Spirals and weaving

Spirals are emergent properties of the tetrahelix, and they appear in both looser and tighter forms, and interweave in both clockwise and anti-clockwise directions (as you may have identified with different colors in the earlier activity). To investigate what can happen when spirals interweave in opposite directions, we can look at a simple toy from childhood: the finger trap (Fig. 8.7).

Experiential: Make or buy a paper finger trap

Although paper finger traps are inexpensive to buy, the process of making one yourself offers subtle points about the helical weaving process that are difficult to learn any other way. They are simple to make, and instructions are readily available online and in craft books (Link 8.2).

Play with the finger trap and feel its surprising behaviors.

A paper finger trap behaves unexpectedly (the trap). When we try to pull our fingers out we discover that we cannot. The helical weaving pattern generates emergent properties, such that straight strips of regular paper are transformed; material that does not have any appreciable stretch on its own becomes a shape-changing tube that can first expand and then tighten around a finger.

Imagine components with transmutable behaviors and emergent properties (biological tissues, for example), in helical weaving patterns. Interwoven helices are found in many places in our bodies; if the weave itself creates an emergent property of stretchiness and elasticity, the geometry could regulate, compound, or accelerate properties already present.

Different kinds of spirals

The Fibonacci spiral drawn earlier starts at a center point and expands outward with an increasing expansion, but spirals of other mathematical proportions can be drawn, and many different kinds of spirals (some specific versions of Fibonacci spirals, such as logarithmic spirals) appear

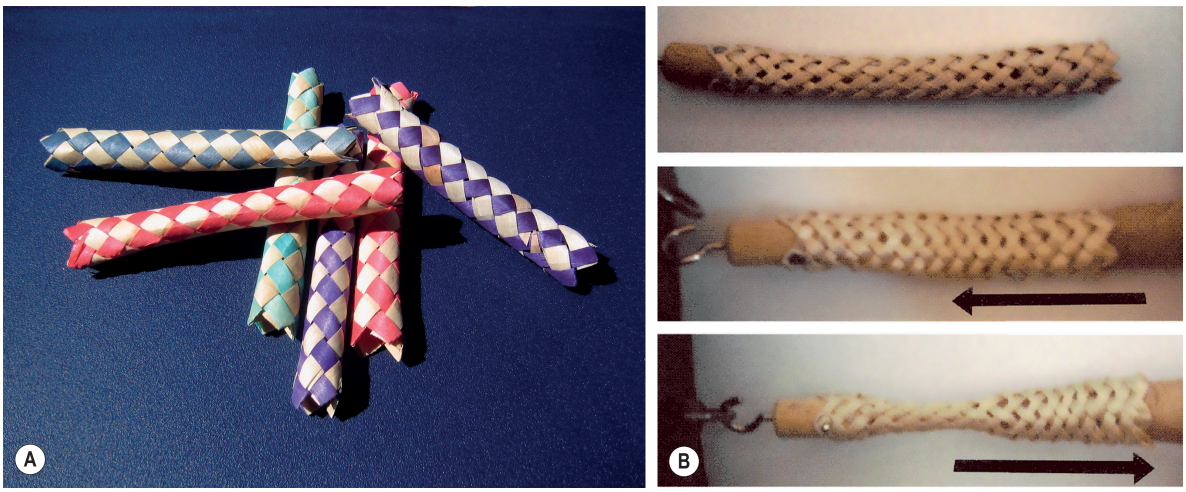


Figure 8.7
Paper finger traps (**A**) are helically woven toys which, when compressed (**B**), expand in circumference, and when pulled, contract in circumference, which can trap a finger placed inside.
(A, carol; CC BY 2.5; B, Redlinux; CC BY-SA 3.0.)

in the natural world. It is useful to be aware that in math, science and engineering there are specific kinds of spirals and helices, and sometimes spirals are distinguished from helices. In math, for example, a *helix* usually refers to a spiral that extends upward, but not outward (like a spiral staircase, the spirals in our tetrahelices, or DNA). However, the original meaning of the word helical is simply a spiral thing, so to keep things as simple as possible here the more general, original definition is being used.

Spirals in the body

Spirals are found in structures all through the body, including our DNA, the helices that tiny actin filaments and other proteins form, the crossed-helical arrangement of collagen in muscular fascia (Scarr 2016), and the readily visible layered and crossed-spiral patterns in the muscles. Even the flow of our blood has been widely recognized as spiralic.

The helical structure of the heart has been well documented since the last century, when Spanish cardiologist Francisco "Paco" Torrent-Guasp first unraveled mammalian hearts to reveal that the muscle's spiral structural continuum was more like a twisted rope (Fig. 8.8). This discovery led to new techniques, such as by Torrent-Guasp's colleague, cardiothoracic surgeon Dr Gerald Buckberg, who taught widely on the helical structure of the heart and pioneered treatment of congestive heart failure by altering ventricular *geometry*. Despite this, of the many commercially available models of the heart, almost none are based on Torrent-Guasp's discovery, and almost all are anatomical, presenting the organ in the shape in which it is traditionally cut and sliced from a cadaver, which gives a very different impression of the organ. We may still be a long way from fully understanding all the spirals of the body and the possibilities for movement these structures may yield.

Spirals in movement

With all these spirals in our bodies, is it any wonder that our optimal movements, and our playful movements are so often helical as well? Soccer players try to bend the trajectory of a ball by kicking a spin into it. Ice skaters spin and spiral around, both on the ice and while jumping. The record holder for oldest woman to swim across the English Channel as of July 2018 (age 66 years, 135 days on date of swim), Pat Gallant-Charette recommends corkscrew drills for training, wherein a swimmer repeatedly switches from front to back (2010). It is interesting to note that Gallant-Charette's path across the channel (Fig. 8.9) is not a straight path, but a zig-zag or spiraling one (a flat image of a spiral may look like a zig-zag, but we live in volumetric space). Even though the shortest distance between two points is a straight line, when actually swimming between two points, one must manage currents, shipping lanes, and other impedances; in this case the path of least resistance involved a spiral.

In the Mexico City 1968 Olympics, USA team member Dick Fosbury shocked the crowds and set an Olympic record for the high jump by twisting his body to go over the bar backwards in executing his now famous "Fosbury flop." Concurrently, in Canada, Debbie Brill had been developing a similar (if not identical) technique, the "Brill bend," resulting in her becoming the first woman in the western hemisphere to jump over 6 ft (1.8 m) in 1970. Both jumpers begin by running straight towards the bar, but then circle around to the left, approaching the bar with a spiral path; as they jump, they twist their bodies to the right, to go over the bar head first and on their backs. Today, a spiraling jump is the standard technique used for the high jump (Link 8.3).

Contralateral movement

We humans make use of spiraling lines through our bodies all the time, and very obvious examples are in the contralateral movements we make every day, movements we make using the opposite arm and leg. From the bottom of a weighted foot up through the leg and body to the opposite arm and hand involves what may well be an incalculable number of lines of force transmission which are fundamentally helical. Typically, we discover the inherent advantages of contralateral movement patterns before we are verbal, so we perhaps only rarely take the time to specifically articulate them to ourselves verbally. Yet almost all of us find our way to them and use them without being conscious of the fact.

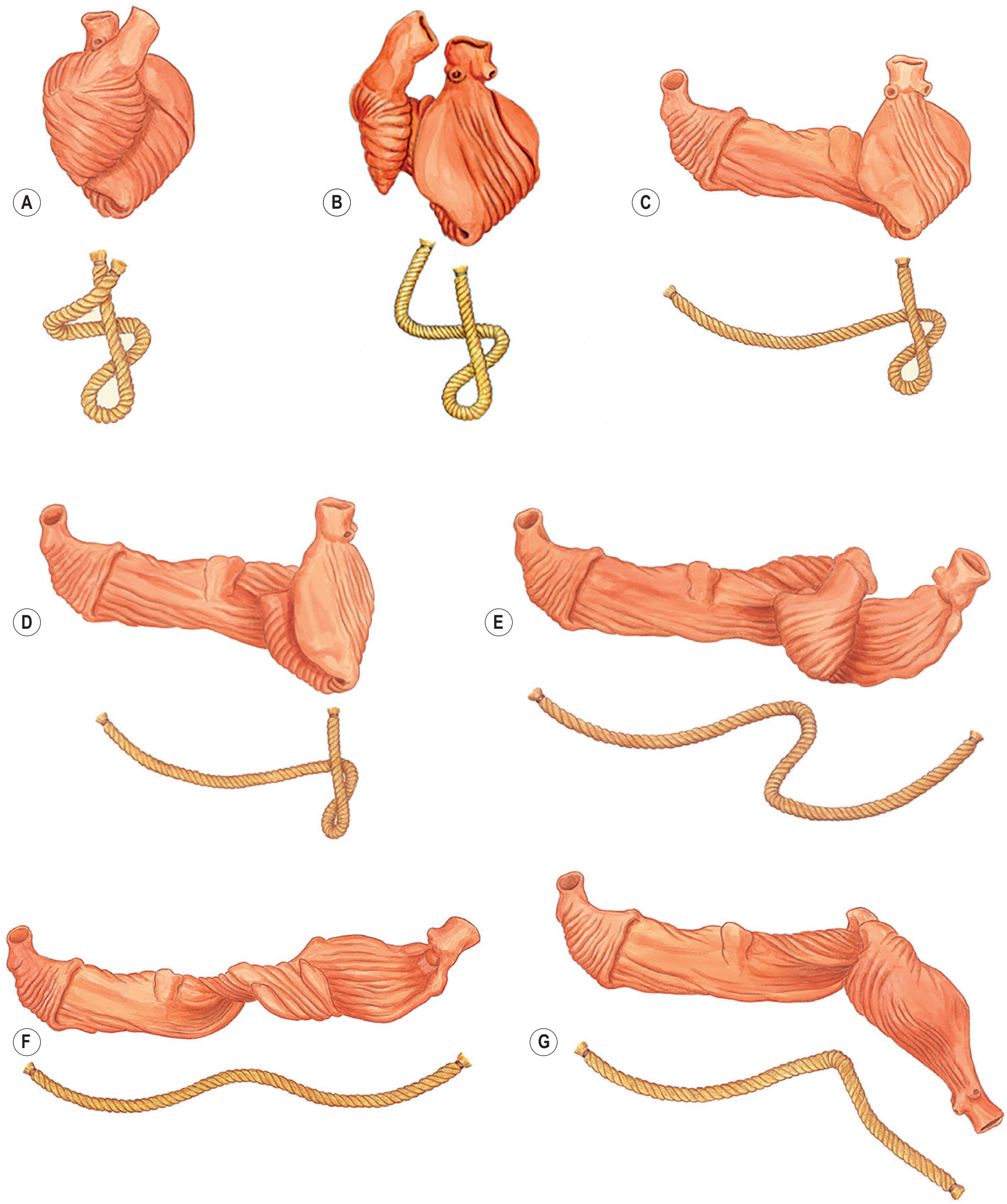


Figure 8.8
Our helical heart: during development, the heart forms by twisting and spiraling in on itself to produce the shape we are used to seeing (**A**). Following the work of his colleague Francisco Torrent-Guasp, Gerald D Buckberg illustrated this shape with a rope, revealing the spiraling continuity within (**B**–**G**).
(Gerald D Buckberg MD, "Basic Science Review: The helix and the heart". The Journal of Thoracic and Cardiovascular Surgery. Vol. 124, No. 5, Nov. 2002. Used with permission.)

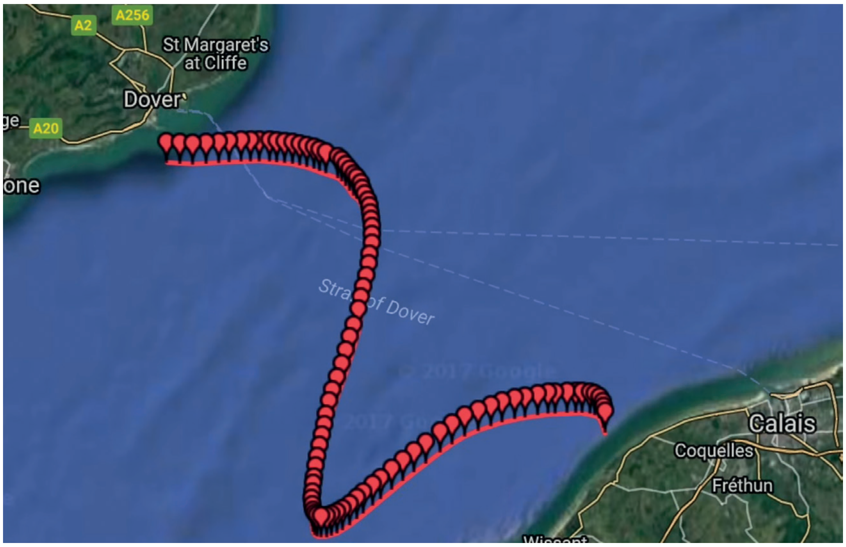


Figure 8.9
Pat Gallant-Charette, at the age of 66, swam a spiral path to cross the English Channel.
(Used with kind permission from Pat Gallant-Charette.)

Experiential: Exploring internal understanding of contralateral movement

Imagine you are about to climb a ladder. Stand and reach one arm up to an imaginary rung. Now, which leg will you pick up? If you are not sure, try one at a time to see if one feels "right" and the other "wrong." If you are still not sure, find a ladder and try to climb. Barring that, you can try crawling your way up a staircase, though the effect is not as dramatic.

Observe a baby crawling, or better yet, get down on the floor and crawl around a bit yourself. Which arm and leg tend to move together? What happens if you try to crawl by moving the arm and leg of the left side together, then the arm and leg of the right?

Walk around a bit. Which arm moves with which leg? How does contralateral movement compare with moving the arm and leg of the left side simultaneously, then the arm and leg of the right?

Throw or roll a ball. When your arm extends forward into the action, which leg is it that most naturally takes the weight of the body? Is it on the same or opposite side of the throwing arm?

Spirals can be energy efficient

The everyday moves of climbing, crawling, walking, and throwing are typically done using the contralateral (opposite side) leg and arm. Doing any of these movements using the ipsilateral (same side) leg and arm will typically feel unbalanced and less natural. For most of us, in the case of trying to climb a ladder with left (or right) leg and arm simultaneously, a sense of falling off to one side feels imminent. Ipsilateral crawling is nearly impossible to do, and at the very least is a lot more difficult than using the opposite side leg and arm to move forward. In walking, we tend to feel mechanical when swinging the same-side arm and leg forward. Similar intuitions typically arise when rolling a ball (as in bowling), throwing a ball, or hitting a ball with a racket. The opposite-side leg and arm will coordinate and generate a series of helical force lines through the system to get the job done, the weight transferring up from the leg to propel the opposite arm. The body will find its way to optimal efficiency whenever possible.

Spirals can distribute forces

Spiral shapes can distribute forces evenly across a system, which we can see with a very simple demonstration.

Chapter 8

Experiential: Observing even force distribution along a spiral

Hold a belt, yoga strap or ribbon tautly between your two hands, so that there is a straight line of energy between the two ends. Begin to bring your hands closer together, and notice that as the weight of the belt pulls it towards ground, the curve that results, called a ***catenary***, is evenly distributed across the material from one end to the other (not lopsided).

In one hand, turn the end of the strap or ribbon upside down from its original position. This effort (force energy) will create a twist in the strap, a spiral. Holding the strap such that the twist remains indicates that more energy is being stored in the system (let go of the strap and the twist will be gone).

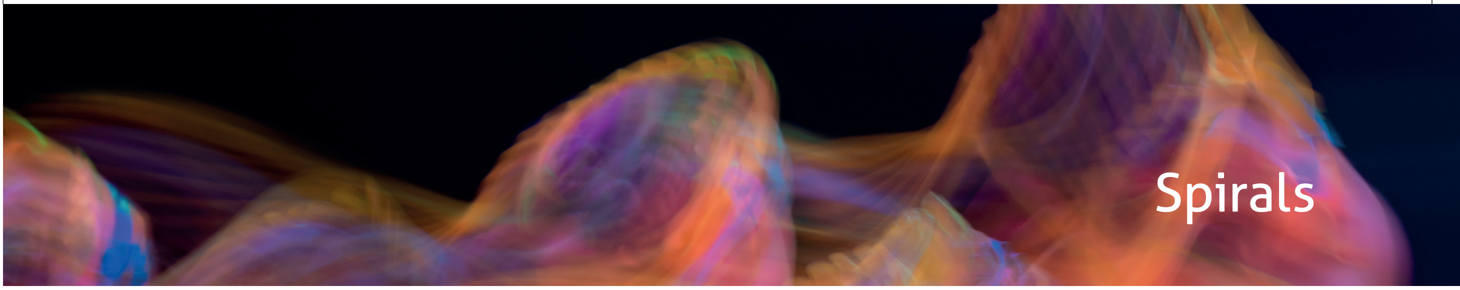
Notice how the forces held in the spiral are naturally distributed evenly along the length of the strap. The curvature does not bunch up in a given section and then barely manifest in others. Tightening the strap between the two hands or loosening it will have no effect on this even distribution of the twist, demonstrating how spirals can evenly distribute forces (Fig. 8.10).

Figure 8.10
A belt or strap that is twisted naturally distributes the twist evenly across its full length.
(Photos © Ana Teresa Ortega.)

Combining energy efficiency with force distribution: Rope

A rope can be made by twining together smaller ropes, or pieces of twine that have, in turn, been made by twisting and spinning together smaller threads (Fig. 8.11). The ancient process begins with the drawing out and

Figure 8.11
Large rope is made from smaller ropes twined together, which are, in turn, made from still smaller ropes, which are made by entwining individual fibers together.
(A, Image by Michal Klajban; CC BY-SA 4.0; B, Image by HiveHarbingerCOM (assumed, based on copyright claims; CC BY 3.0).)



spinning (twisting) of the initial fibers, and those threads can be entwined with others, until the needed thickness and heaviness is achieved.

It may not seem materially efficient to twist strings together to make a thread, because the process shortens the length of any individual fiber. The spinning together of threads, however, delivers longer, stronger, and more useful pieces, as the spinning allows shorter threads to become part of a whole that can become much longer than any individual fiber within. In terms of function, winding the threads around each other can result in both improved force distribution and material efficiency. The force of a straight pull on the length is distributed through a nested system of interwoven spirals. The threads pull together, rather than alone.

To make a simple two-ply rope from two threads, one must follow the initial twist of the two threads, but intertwine them in the opposite direction. So, to rope together two counter-clockwise threads, each thread itself is twisted counter-clockwise as the two are wound together in the opposite, clockwise direction. This twining of opposing spirals at different scale levels has the effect of "locking" the threads together so as to prevent unraveling.

In light of this, it is interesting to consider that tetrahelices assemble geodesically with inherent twists and create a configuration that has spirals at three different scale levels of alternating chirality. More relevant to our study of biotensegrity, tensegrity icosahedrons, themselves having an inherent helicity, can come together with others to create spirals, and spirals within spirals in interwoven tensegrity masts (Fig. 8.12). Scarr has discussed the many helices of our bodies which, as in a rope, are found at many scale levels, from the molecular on up (2018, pp. 17, 67, 68, 119).

Exploring our inner spirals

Just as with the yoga strap we can think of distributing the twist of a curving movement evenly across the body. Consider the potential value of distributed helical action in the body. Without it, not only may the twist get unduly concentrated in one area, but nearby zones that may benefit from a spiral pulling action, such as a morning yawn and stretch, could be deprived of a beneficial tug, as the effect of the spiral pulling can be damped if there is less integration and connection throughout the system.

Figure 8.12
Steve Levin's model of icosahedrons self-assembling and closely packing into a double helix (**A**), and the author's recreation of a similar model (**B**). This static shape model offers insight to possibilities for living tensegrity icosahedron force diagrams manifested in transmutable tissues.
(A, Stephen M Levin, used with permission.)

Experiential: Pushing hands against the sky: distributing your spirals

This is a very old Chinese exercise. Coming across millions of people and thousands of years, there are many versions of it out in the world (and many names!). Including it here is not meant to be interpreted as Qi Gong instruction, but Pushing Hands Against the Sky provides a nice illustration of how awareness of tensegral structure can be applied in exploring more integrated, comfortable and sustainable movement possibilities.

The basic shape is made by standing with the feet parallel, the legs loose, and the arms extended above with

the palms turned to the heavens. Then you press against the sky. To start, just briefly explore the shape.

You can probably see how beginners often try to create the shape by raising the arms up with the shoulders, and turning the hands over with the wrists. This concentrates the turning action in the shoulders and wrists. Instead, this shape can be created in a more integrated way, with the helices and effort distributed throughout the entire system.

Move into this shape slowly, feet open and relaxed, but pressing a bit into ground. Try to become aware of the incoming upward direction of the ground reaction force. As this force comes in, it meets with your omni-helical, many scale-leveled, tensegral structure. Allow the force to be managed by your many internal spirals to come up from the feet, through the legs, and into the upper body. Imagine and perhaps even feel the possible spirals and helices in the body as you allow this upwelling of spiraling energy to come into your arms and hands, lifting them and turning them as a natural extension of what is already happening in the lower body. Once this continuum of spiraling energy feels activated throughout, gently press a bit, both down and in with the feet and up and out with the hands.

We know that many of our muscles wrap in alternating spiral patterns, and this spiraling can be found at all the deeper and more internal levels of the body, right through to our DNA. Can you feel the helical structure of your own body? How might this influence a movement? How might improved distribution of forces throughout the system help us to improve functional efficiency and avoid injury? Recall that forces applied to the six-strut tensegrity are distributed throughout the structure instantly and everywhere. Ideally for this particular activity, all parts of the body will be involved with this upwelling, spiraling extension.

Only do as much as feels right and good, of course, but improved integration and distribution should bring with it an overall release and comfort, a sign of greater energy efficiency. The more comfortable the shape, the easier it is to maintain it, and it may even feel so good that one is reluctant to let it go. Particularly if this shape is new to you, keep your time within it to under three minutes.

Can improved understanding of our structure help us to move more easily and safely? Might it help us to better protect ourselves and our students and clients? What would it mean to be able to move more tensegrally? In many ways we already naturally do this. A very practical extension of the concept of optimizing the use of spirals in the body is cross-shoulder carrying. Instead of carrying a shoulder bag with the strap on the same-side shoulder as the bag, try using the opposite shoulder instead. The strap needs to be longer, but the weight of the bag will be brought in closer to your center of gravity, and more easily distributed between the legs, reducing the effort required for carrying.

Volume-maintaining

Martin discusses how "Tensegrity structures have a spiraling and volume-maintaining response to load" (2016, p. 49) and has demonstrated the difference between a weakened, non-tensegrally approached and a more global, tensegrally approached movement of the neck. She demonstrates a curving movement using two different tensegrity towers (or masts). One mast is made with struts which resist deformation, the second has some strings in the middle area that readily deform by becoming longer when pulled. Martin shows how, in the second mast, the deformable strings weaken that particular area (and by extension, the entire structure) by causing it to collapse in the middle area when under load. As Martin bends the first mast, she shows the optimal response from the tensegrity structure: "space-maintaining, not collapsing, and all the elements are intrinsically involved in the movement." When she bends the second mast, it responds "with a sharp angle … not all of the elements are involved in the movement, but only in the area of weakness" and she points out that this weakness creates a non-optimal response from the tensegrity structure (2016, p. 101).

On Steve Levin's website (biotensegrity.com), while lifting her eyes to look upward, Martin shows how most of the movement can be concentrated in one small area of the neck, creating a sharp angle, similar to the response of the second mast. A different version of looking upward can be done, she demonstrates, with a more integrated, distributed, space-maintaining, and tensegral action.

This results in a more comfortable and (we presume), a more sustainable and safer movement (Link 8.4). Martin also demonstrates how helical movement can be a way of possibly restoring space in a collapsed or compressed system, “the beginning of functional recovery” (2016, p. 101).

We look upwards many times every day, but different actions may achieve the same result. As we move from a given “A” to a given “B,” the movements can seem the same in the macro, but we may miss what is happening at the deeper levels of our systems, unaware of whether our distribution of forces is effective or lacking, since the ultimate goal is reached either way.

What relevance does all this have to us as movement teachers and movement therapists? Since biotensegrity is new science, researchers are constantly seeking the links between what we see in models and what is found in biological structure. Movement instructors, coaches, and therapists can add a third kind of bridge to this growing network of information. We are simply interested in what works. In healing, health maintenance, performance, and physical skill and development, our interest is in optimization of healthy function. Circus performers, dancers, and musicians must find optimal functional movement if they are to perform several times per week, for hours at a time, over a period of months and years. Professional bodyworkers must find optimal movement strategies both for themselves (in order to sustain their practices) and their clients. As professionals in these fields we have a very different set of constraints from conventional laboratory researchers, and a very different combination of freedoms and responsibilities. What we feel and experience in our own bodies and the bodies of our clients and students can be informed by our physical models in a very different way from our scholarly or laboratory researcher peers, and may provide a valuable fresh perspective.

Since “it is the geometry that underlies the mechanics” (Scarr 2014, p. 49), recognition of our inner spirals and their resultant in-out-around biomotion, capability for material efficiency and force distribution and potential for use in self protection and restoration gives us a powerful resource for our biotensegrity toolkit. Understanding the particular potential of spirals within spirals opens yet another door for study, as the patterns generated by nested and interwoven spirals are not the only ones found in our system – which brings us to our next step in exploring biotensegrity: patterns.