Minute Sketches: A tool for problem solving

(* intended to be used with '<u>Folded</u>-<u>Lists</u>'; see that description as well)

Here I describe a method to turn any concept, structure, or event into a simple sketch that can be easily practiced and easily recalled. I also describe how to use those sketches in science, to solve problems or make predictions. Finally, I also try to convince you, the reader, that this is how scientists work and think. Whether you plan to be a scientist or not, this way of approaching learning will, automatically, give you a straightforward method to solve problems.

For those interested in the technical background, each minute sketch is a 'chunk'. Learning to use and create your own minute sketches is also training in the 'chunking' that eventually makes you an expert. (And yes, 'chunking' really is the technical term, among the my favorite terms from the research on learning and memory!)

I. The concept of a minute sketch

Minute sketching was developed based on research on how people learn best and how they use what they learn, including the following:

- Humans are highly visual, and use images, gestures, and symbols extensively in thinking.
- Different brain areas process images, written text, and spoken language.
- Humans have one focus of attention at a time; you can read text OR comprehend an image, but not both at the same time.
- Memory for physical skills and specific movement tasks (non-declarative 'skill memory') is independent and uses different brain areas from memory for words and observations (declarative memory). Skill memory is created by and stored in its own separate brain areas. (Other names are 'motor memory', 'muscle memory' or 'kinesthetic memory'—these all refer to the same thing.)
- Motor memory is <u>far</u> more permanent than memory for words & phrases.
- The fewer lines in a diagram, the easier it is to copy and remember.
- It is easy to recall a drawing that can be created in less than 30 seconds, given just afew minutes of practice a day over several days.
- Experts don't think of more things at a time than novices. Experts hold the same number of chunks in their working memory at one time as do novices. BUT, experts learn and automatically recall more complex chunks. Thus, where a novice might remember only seven single digits from a long series of numbers, an expert (at memorizing numbers, in this case) would remember seven chunks, each of which had multiple digits in the right order. Each chunk might be an easy-to-recall date (1492) or phone number (911). By chunking, an expert can quickly think through more complex problems and situations than a novice.

A minute sketch is designed to teach students how to simplify a new term or concept to a sketch that has everything necessary to capture the concept for them. It is designed to be drawn quickly (in less than a minute; my actual rule is less than 30 seconds) so that a concept or term can be reduced to essential elements and held easily in the mind once it has been learned as a single chunk. (Anything too complex for a single minute sketch can always be captured in a series of two or more connected minute sketches.) Minute sketches are intended to involve motor memory (or 'kinesthetic memory') in order to provide a second way of learning that is independent of word learning. This motor memory is also much longer lasting than word learning (or 'declarative memory'). Further, words are banned from a minute sketch! This allows the brain to use only image-processing visual areas and motor areas when creating and using a minute sketch. When words are on an image, the brain has difficulty with comprehending the image, because the image processing areas have to compete with text processing brain areas. Visual attention can be on only one or the other, text or image, not both at once. However, since associating the words with the correct terms is critical when actually using the concept, a second tool is combined with minute sketches to make the connection between images and terms. **Thus, Minute sketches are most useful when combined with a second method to associate appropriate terms, key words, and phrases with sketches. A method to do this is described elsewhere on my site, as a '*Folded List*'.**

The process of minute sketching described below is based on a decade of university student use and their feedback on what works for them. Students are successful when they can (1) create minute sketch diagrams and models that capture a definition or a concept, and (2) use their minute sketches to produce logical solutions to novel problems.

II. Instructions for minute sketches: Four steps

1. From lecture notes or a text book chapter, identify an important process, concept or structure.
2. Write down the term for the process, concept, or structure, and then list the key words from the definition or explanation.
3. Create or find symbols for each key word or event.
4. Combine the symbols in a sketch that captures the definition or concept.

***Hint**: It is easiest for most users to start by studying with pre-prepared minute sketches for something they want to learn. Once someone understands how to use them, and (most users tell me) once someone can tell that they remember something very well surprisingly quickly, it makes more sense and is easier to learn how to create their own minute sketches, and do their own 'chunking' on the way to becoming an expert.*

Step 1. Identifying important concepts or definitions.

Start with the most important item to learn, either in your notes or a book. As a beginner, you'll just have to make an informed guess as to which is most important. It doesn't matter if you're not exactly right. With practice, you can figure this out: the most important topics are the ones which, if you don't know them, will make it impossible to understand more of another topic. For example, if you're studying molecular genetics, then DNA is critically important; you can't understand anything else without it. The role of transfer RNA is less important; you can forget it, and still have a fairly complete explanation of many topics in molecular genetics, but you won't be able to solve every problem that involves the growth of new proteins. The molecular structure of ribose sugar is probably unimportant; you can forget it and might still solve every molecular genetics problem you're given.

Of course, if a teacher tells you which things are important, that will make this task simpler. However, it's still incredibly valuable to develop this skill on your own. You'll be making decisions on what is important to learn for the rest of your life. You'll save a lot of time if you can decide that many things are not worth studying.

In the examples I give you here, we'll capture (A) some basic chemistry, and (B) the complex biological process of DNA to RNA to Protein in minute sketches.

Step 2. Write down the term and key words from the definition or explanation.
(A) Key words for basic chemistry might include element, proton, neutron, electron, ion, specific important elements, water, crystal, covalent bond, sharing electrons, ionic bond, dissolved ions.

(B) Our second example involves DNA transcription and translation: the processes by which genetic material, a section of a DNA molecule, is first recopied as the related molecule RNA, and then the RNA sequence is used to assemble amino acid molecules in the correct order.Key words from a more complex concept, n might include: gene, promoter, exon, intron, RNA polymerase, messenger RNA, ribosome, transfer RNA, and amino acid. There are other possible terms to include, such as 'codon', 'anticodon', 'start codon', and 'stop codon' ; you decide when you've included all of those needed for the problems you'll have to solve.

Step 3. Create or find symbols for each key word or events. As you do minute sketches, you'll start picking up a set of symbols that you'll take from lectures or books or invent for yourself. If you can use symbols that mean similar things each time you use them, you'll save time. It is important that the symbols in your sketch make sense to you. They do NOT need to make sense to others, but if you've got good symbols, other people will understand them.

For example, movement or time can be indicated by arrows. Small symbols can indicate individuals (individual people, animals, molecules, or whatever). Different small symbols can indicate different people, elements, molecules, or animals.

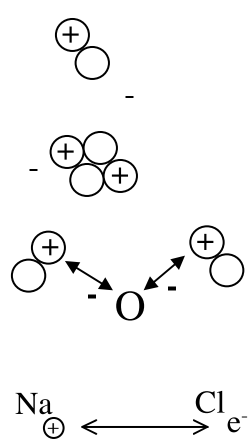
(A) A circle with a plus might be a proton; an empty circle a neutron, and a 'minus' sign an electron (an electron is much smaller than a neutron or a proton). Double arrows with a minus sign in the middle might indicate shared electrons, while double arrows that have a proton and an electron at opposite ends might indicate attraction of opposite charge without shared electrons in an ionic bond. Water molecules might have very tiny plus signs near the hydrogens in order to indicate that, even though the electrons are shared, the electrons spend more time near the oxygen, which gives the hydrogen a slight positive charge (on average) and the oxygen a slight negative charge. That might give us the following minute sketches:

Element
proton
neutron
electron

Ion (+1)

Sharing electrons
covalent bond
H_2O

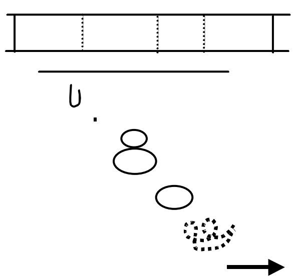
Not sharing electrons
ionic bond



(B) For our more complicated example, a double line might indicate DNA (which has two long paired strands) or a cell membrane (which has an inner and outer layer of molecules). Some possible symbols for our example include:

DNA: double line, with dotted lines across to indicate different parts of a gene (promoter, exon, intron).
mRNA: a single line
tRNA: a curved squiggly line
amino acid: a small square
ribosome, a small oval on top of a larger oval
RNA polymerase protein: a solid or dashed circle
Some other protein: a twisting dashed line
Time or movement: an arrow

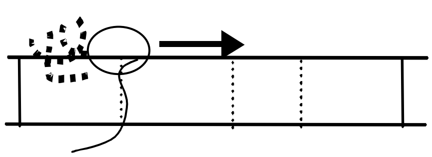
Here are the symbols, in the same order as the terms above:



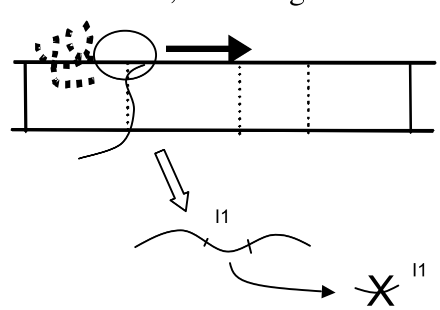
Step 4. Combine the symbols in a sketch that captures the definition or concept.

(A) I've already done that in the sketch above for our basic chemistry example.

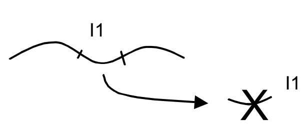
(B) For our more complex example, we might start with:



Here, I've started with DNA transcription: two parallel horizontal lines for DNA, a transcription factor plus RNA polymerase bound to the DNA, some messenger RNA starting to be produced, and with four segments of the gene. The four segments represent the promoter region, then the first of two exons, then an intron, and then the second exon. For a novice, this is a good sketch for a single chunk.

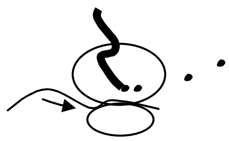


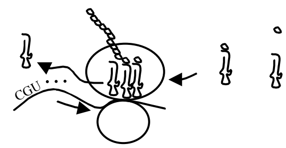
Below is the second part, mRNA intron removal:



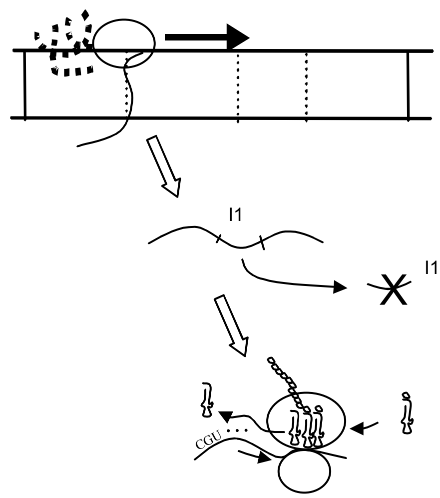
To the <u>right</u> <u>above</u>, I've combined the two parts in a single sketch. Here I've shown the new mRNA, out of which the copy of the intron is cut and broken down.

Next (below left) the two exon segments of the mRNA have been reconnected, have encountered a ribosome (the two ovals), and the RNA is moving through and being translated into a protein (the thick line) of amino acids (the dots). Below on the right I've shown the same thing, but also shown a triplet codon (CGU) and transfer RNA coming in from the right. tRNA needs to have a correct amino acid bound to the tRNA, and then the tRNA-amino acid pair can move into the ribosome, where it binds to the correct codon gives up the amino acid to the growing protein.



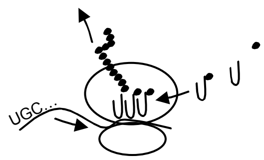


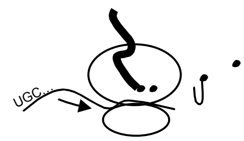
A novice would learn each of these separately, each as a single minute sketch, and each as one chunk. An expert might hold the entire thing as a meta-chunk (several chunks connected to allow the group to be a single item in working memory)—the sketch below.



Realize that to create and use minute sketches, you first have to hear about and <u>understand</u> the whole process. Without an explanation, my minute sketch makes no sense at all. However, once you've read the chapter or heard the lecture, this sketch actually captures what happens in DNA→ RNA→ Protein. One or more transcription factors (or enhancers) plus RNA polymerase bind to specific sequences of DNA, allowing RNA polymerase to move along the DNA and make an RNA copy, including both exons and introns. Introns are cut out of the RNA strand, and the exons become the messenger RNA. mRNA encounters a ribosome. RNA begins to move through the ribosome. Transfer RNA's, each carrying their specific amino acid, bind to the mRNA in the ribosome, and their amino acid is added at the end of the growing chain of amino acids. Eventually, the ribosome reaches the end of the mRNA, and the chain of amino acids, now a protein, is freed.

Notice that there's nothing in here that isn't needed; no extra lines, no colors, no shading (except that the proteins have more dots than needed—you could use fewer dots). That makes your minute sketch quick to draw and simple to think through (and keeps it the size of a 'chunk'). And notice: there are no words on the diagram! At most, there are only single letters or initials, but no abbreviations (when you can, don't even have letters on the sketch!). Don't ever break this rule. When you need to know words, combine minute sketches with *folded lists* (see instructions on my site). With practice and resketching, your minute sketches become simpler:





I've made the process seem simple. In fact, when you start, you'll be slow to create new sketches. The hardest part is learning how to create good sketches, but that's also an important part of studying. One of the reasons it is hard to create minute sketches is that you have to understand something before you can make a good minute sketch. Once you know the method, if you can't create a good minute sketch for something, then you don't yet understand the topic well enough. Use minute sketching properly, and it will force you to REALLY learn topics, not just memorize them. Once you've learned the method, creating new sketches becomes something you can do quickly as soon as you understand a concept.

Quite a few of my students have learned minute sketching just from these instructions. However, you'll probably learn faster if you have someone who is good at it look at your early sketches and show you how to improve them. Most of my students learn the method faster when they get this kind of help.

III. Overview of how minute sketches help. Importantly, the sketch shows all of the events in a way that is easy to remember, easy to scribble down on the margin of an exam (or even use as part of an essay answer), and helpful if you need to solve a problem.

Next, minute sketches help you remember the order or sequence of events. You can only sketch one thing at a time, and the automatic tendency is to sketch a series of events from beginning to end.

Minute sketches are helpful in solving problems. They give you an image to use as a tool to test possible answers. Imagine that a teacher asks how DNA transcription and translation might change in a cell of a person who is starving. With a minute sketch, the question becomes straightforward to answer. Look at the diagram that shows transfer RNA and amino acids. A starving person would have less food, and so less protein in their diet, and therefore fewer amino acids (useful to have or create a minute sketch for food and nutrient stores). With fewer amino acids, transfer RNA will take longer to bump into and bind a new amino acid (also useful to have minute sketches for random molecular motion). If so, there will be fewer transfer RNA's bound to amino acids, and so it will take longer for a new transfer RNA with amino acid to bind to the ribosome. Answer: creation of new proteins should slow down, for reasons that you KNOW are logical. The key is that with a minute sketch, you have an image that actually represents the real events. If a teacher tells you something has happened to X, you just look at your sketch to see what would change. (Here's another question: What might happen to the process if we added a drug that bound to and blocked the enzyme that cuts out introns?)

Memorizing only words describing a process is incomplete without some sense in your head of what's actually happening. I doubt that memorizing words alone is sufficient for any problem like those above. (And I know that my students cannot solve these exam problems from definitions alone.) If you need to use concepts to do problem solving on an exam, memorized words alone won't help at all. I might be able to memorize a Russian novel and I could '**know**' it perfectly, but that wouldn't help me answer any questions about the plot. (Why not? I don't understand Russian….) My students can '**know**' biology in great detail, and still fail an exam that asks them to solve problems.

What else? Minute sketches help you think like a scientist. A minute sketch is a hypothesis! Every minute sketch is a model for a structure or a function or an event. In the sciences, new models (new minute sketches) are not yet known to be correct—we have to test them. How do we test them? In most of science, we test our model by changing one part of our minute sketch—taking something out, adding more of it, or doing something to shift it. We then predict what SHOULD happen, based on our model (our minute sketch). That's our prediction. Then we test it in a real experiment. If our prediction is correct, then we have support for our hypothesis (our minute sketch). If our prediction turns out to be wrong, then there is an error in our model (or our experimental method….). Getting good at using minute sketches helps you get good at creating, using, and thinking with hypotheses and predictions in problem solving.

IV. How long does it take?

First, how long does it take to actually get a minute sketch into your memory so that it will stay? My experience for most people is that redrawing your sketch 2 or 3 times a day, while thinking through the process, on at least three different days gets something fairly well into memory so that it sticks. That may seem like a lot, but it isn't. Remember that minute sketches are small, and each can be redrawn in 30 seconds. Each time you redraw it you think through the process as you sketch (again, that's important). Because you'll find that you automatically recreate your sketch in order, from beginning to end of a process or structure, your motor memory will help you keep track of the order for you. Because you're using more of your brain than just your declarative memory brain areas, ADDING your motor or muscle memory, you'll have more ways to remember the sketch (the 'chunk'). Often a student tells me that they couldn't remember something until they decided to just start drawing, NOT YET KNOWING what they would eventually draw.

When can you practice? You can use study time that was never useful before. It turns out that using your motor memory to draw while also using your declarative memory to think through your sketch makes it easier to concentrate. Most people find that they can practice and redraw their minute sketches in noisy crowds, on a bus or plane even when others are talking, or while other students are settling down just before class. You'll find yourself surprised the first time on an exam when you cannot remember something, start to sketch in the margin, and your motor memory brings it all back.

Second, how long does it take to learn how to use and make your own minute sketches? If your brain already sort of thinks this way (in other words, if you tend to emphasize visual learning this general way, and if you like sketching), then you might improve very quickly. A very few of my students who try minute sketches go from C's, D's, or even F's to A's in a single exam, after working hard with minute sketches AND folded lists within weeks or a month or so.

MUCH more often, it takes 3 months, 6 months or even a year to get good at using this as an effective study technique. Many of my students tell me, at graduation (two or three years after I first showed them minute sketches), that they tried minute sketching, couldn't get it to work, and so mostly gave up. BUT, every now and then they tried again, and by six months or a year later, they were using minute sketches in all or almost all their classes. Many also tell me that they're able to learn things faster, with less study time than in the past, while also doing better on exams.

V. WHY do I think this is so important?

Because scientists think in minute-sketches (though that's not what we call them). Scientists think about their science using what we call 'models' that look like the figures and flow charts and diagrams we put in textbooks. Those figures (or models or sketches) aren't there just to help students learn. The figures are available for textbooks because that's how scientists think about the topic. For example, no scientist I know memorizes definitions only as words. We learn using mental models that describe the topic as an image. If I need a definition, I describe the sketch or picture I see in my head. (If I use a definition enough times, I can end up memorizing the words as well, but without trying.) Even scientists who tell me, at first, that they don't think in pictures actually discover that they do. So far, for every scientist I've asked to, 'close your eyes, and explain _X_ to me', has found that he or she does indeed have images in their head, and they describe them to me like minute-sketches. I suspect there are probably exceptions, but I haven't met them yet.

So how commonly do my students think in diagrams and pictures when they come into my classes? Most don't. Very few of my students think in simple sketches and simple models, perhaps because they've never been taught an easy way to do so. They think in words, they memorize definitions, they read sentences in textbooks over and over again, and they learn which words go with other words, and which terms go with other terms. Most RESIST thinking in minute-sketches.

Does it matter? Yes. When I ask most students to USE their science to solve a new problem or make a new prediction, they're not good at it. The definitions don't help them very much. It's as if I taught them basketball only by having them memorize definitions, descriptions of movements, and rules. They might be able to explain basketball, but they couldn't play a game. How do you get good at basketball? By practicing how to play on the court, by drilling the basic moves and plays, AND by learning rules and terms (free throw, lay-up, pass, basket, traveling, foul). If I want students to learn how to do science, I need to teach them the words and to practice the skills to play the game. If you want to develop your ability in science, you need to know terms and be able to explain concepts in order to work with others & use information from others. Scientists also need diagrams and models to think about their science and use their science to solve problems. For any problem involving structures, functions, or interactions of physical objects, diagrams are much easier to manipulate to solve problems than are words. If you want to be able to think about and solve scientific problems, then you need to be able to manipulate diagrams (on paper or in your head).

Of course, terms are necessary to describe what you've done and to communicate with other scientists or on exams—that connection is made with ***folded lists***. Folded lists are another topic on my web site.