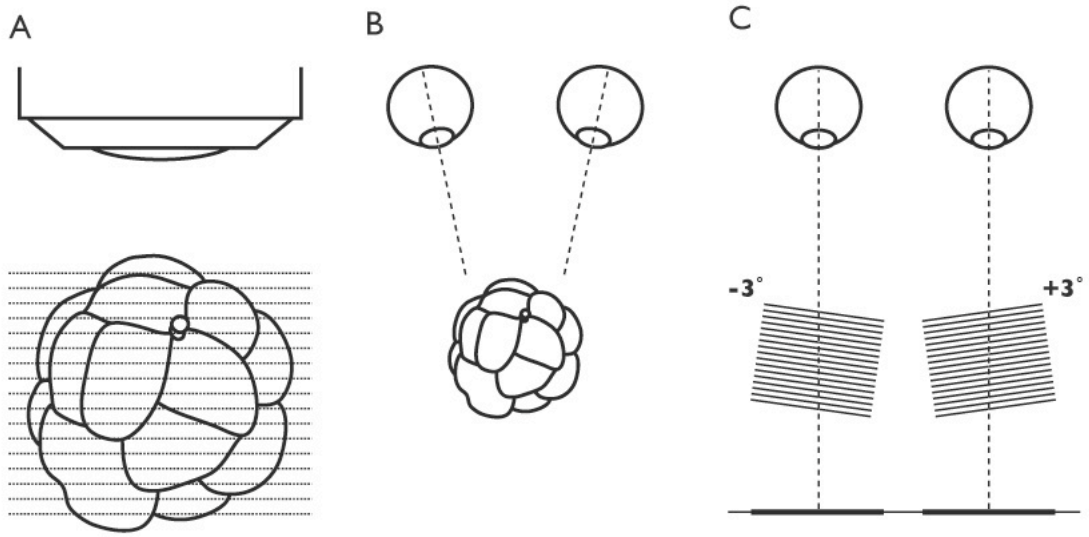
**How to see stereo images** written by G. von Dassow

The principle thing to realize is that most people see in stereo all the time: your eyes, when looking at an object held in your hand, see the object from slightly different angles. From the point of view of your right eye, your left eye is peeking a bit round to the other side, and vice versa. Of course this varies with distance, how far your eyes are apart, etc. And of course a few people have different enough eyes that they don't see in stereo. But most people can do it with a little practice.

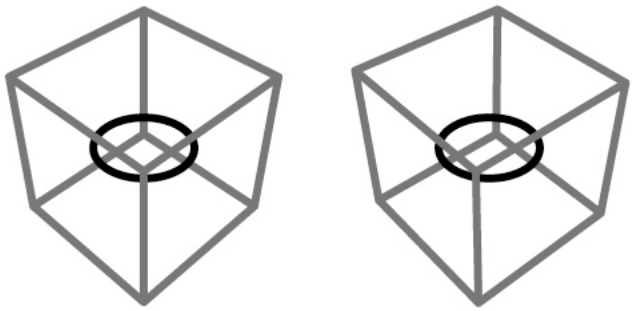



Given a three-dimensional data set, say a stack of sections made with a confocal microscope through an embryo (A, above) we can render it into a two-dimensional image from any angle we want. We want your eyes to look at slightly different sides of the specimen (B). In order to make stereo images, we will render one image that "belongs" in your left eye, and one image that belongs in your right eye by choosing the angles at which the images are projected into a plane (C). Then all you have to do is trick your brain into allowing the left image into the left eye and the right image into the right eye at the same time!

That's easier said than done (until you learn how). From infancy, you have been honing a valuable reflex which makes your eyeballs focus in the same plane at which the optical axes of your eyeballs converge. Thus, when you look at an object held in your hand, the paths from your pupils to the object converge at a 6-8 degree angle, meeting at the object, and your eyeballs reflexively focus at that plane. When you look at the horizon, the paths from your eyeballs are nearly parallel, and your reflexes focus each eyeball far away. Useful as it is, you must somehow defeat that reflex if you are to see stereo images.

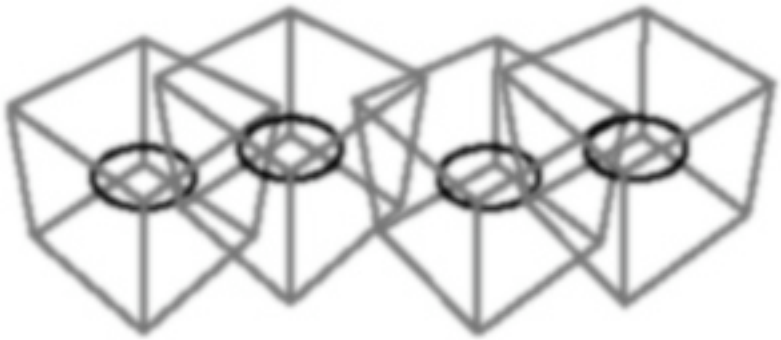
There are two ways to see stereo images without glasses: one can either train one's eyes to diverge, while focusing on a plane much nearer than the horizon, or train one's eyes to converge (cross) while focusing on a plane much farther away than the convergence point. The advantage of crossing your eyes is that you can more readily see stereo pairs at any size (e.g., on a wall). The advantage of diverging your eyes is that your eye muscles will be relaxed instead of tense. I've never met anyone who could do both. It's probably just a matter of which you manage to learn first, but everyone is convinced their way is easier and better. I can only do the divergent way (which naturally feels infinitely superior to that other way), so the advice here applies only to divergent viewing.

Try a simple stereo pair first:



Of course, it's obvious what it is: an ellipse inside a cube. But perhaps if you've played with "Magic Eye" drawings before, you can already see the stereo effect, in which case you're done.

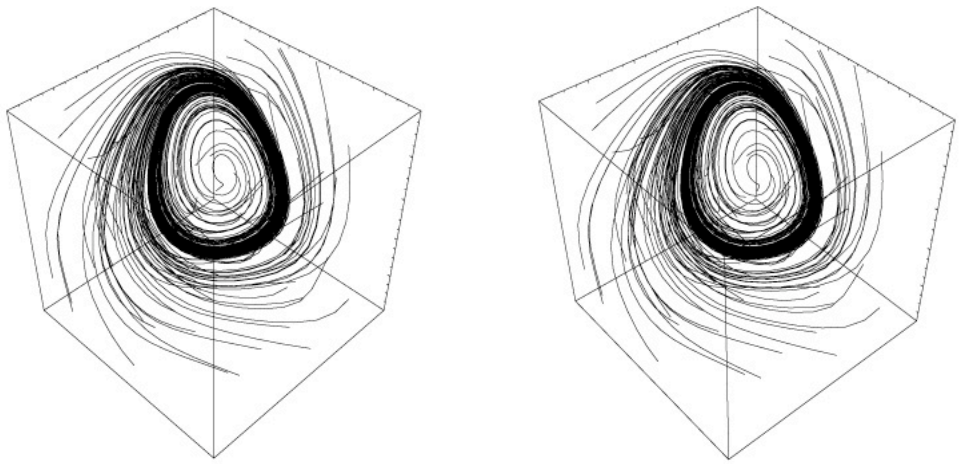
**Step 1: space out.** The most important thing to remember is not to try, initially, to focus on anything. As you space out, your eyes will diverge. This is why, when you are listening to someone give a long boring monologue and you stop paying attention, they will say "aren't you still listening!?" They will have detected the subtle body-language cue that your eyeballs are no longer converging upon them, but are instead looking past into the distance. At any rate, as your eyes diverge, everything nearby will double: whatever you were looking at, you'll start seeing two out-of-focus copies of it. Now the cubes might look roughly like this:



**Step 2: make the out-of-focus copies overlap just right.** In order for your brain to think it's looking at a real three-dimensional object, it has to get the right mix of cues from your eyes. In particular, the diverging images have to come exactly together, and you have to learn to herd them together without trying to focus on them (or you'll lose it). If they're not on the same level, you might need to adjust the tilt of your head by wobbling it slightly from side to side, and relax further until this happens:

**Step 3: let focus come to you.** Don't try, because trying engages reflexes, and you are trying to defeat reflexes. It's the part in the center that matters: the portion of your visual field in which an image for your left eye coincides in space exactly with an image suitable for your right eye. The central, overlapped part will be flanked by two images that won't look 3D. Your brain will hopefully discover that in the middle there is something sensible to focus on, and do it for you.

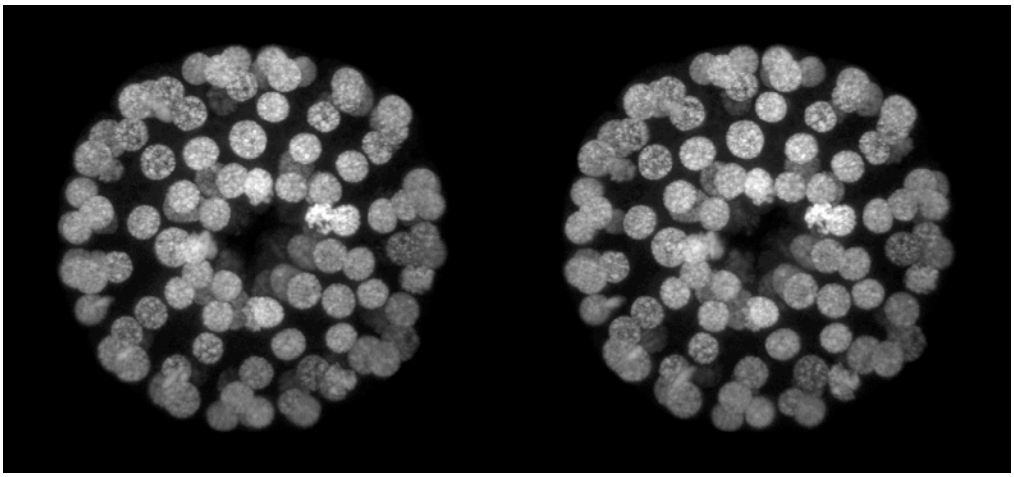
Now if you get the simple one a page back, try something more elaborate:



Once you get that, then try the images of embryos on the next page. Many micrographs are on a black background, which some people initially find harder, but be patient because it's worth it and comes in handy in lots of places (no, really). Beginners find viewing larger images more difficult, especially moving images, so if you are looking at them on screen, try scaling them down.

To make stereo pairs from a stack of confocal images using ImageJ, first adjust the brightness and contrast as needed and make an 8-bit copy. Make sure that the

calibration is set properly (so that the vertical spacing between slices is accurate). Then use the Image—>Stacks—>3D Project... command; select brightest point for the projection method, Y-axis for the axis of rotation. For a 6-degree angle of separation, specify 357˚ for the initial angle, 6˚ for total rotation and for the rotation increment. Set both depth-cueing options to 0. The result will be a two-frame stack. To display them side by side as a stereo pair, use the Image—>Stacks—>Make Montage... command with 2 columns, 1 row, and 1.0 for the scale factor. You should get something like this:



If you try this and it comes out looking backwards (or, inside-out, as it were) then reverse the order of the two frame stack, then make the side-by-side montage again. You can also make a stereo triplet which allows you to see from both the front and the back at the same time. This is also user-friendly for both convergent and divergent stereo viewers. Simply add a new blank frame to the two frame stack in ImageJ, copy and paste the first frame into the third, and then make a three-column montage like this: