PART I: A PRIMER ON SUBCELLULAR SCALE

#	Visuals	Voiceover Script
1	CLOSE ON – HUMAN FIGURE on a plain background. The HUMAN FIGURE looks at examples of diagrams of cells with differing sizes of organelles while camera dollies around them until an over the shoulder shot. The HUMAN FIGURE looks at their finger, and the camera ZOOMS in to focus on their fingerprint. Examples of cells (sperm, leukocyte, fibroblast, macrophage, oocyte to scale in 2D) pop up with labels. 30 fibroblasts line up to make a chain with the original fibroblast.	In cell biology, everything we study is too small to be seen with the naked eye. We use diagrams to learn about cells, but it can be hard to judge the sizes of things we've only seen in images. How big *is* a cell? One thing we can do is compare microscopic sizes to something we're already familiar with: ourselves! One ridge on a fingerprint is about half a millimetre, or 500 microns across. Cells can be a variety of sizes depending on the tissue or organism. Let's take a closer look at the *fibroblast* here. A large fibroblast can be 16.5 microns long, small enough for 30 of them to fit in one ridge on a fingerprint.
2	One FIBROBLAST grows suddenly, surprising the HUMAN FIGURE. The FIBROBLAST drops off their finger and onto the background plane. The FIBROBLAST appears as long as the HUMAN is tall. A scale bar in the corner of the screen gives a constant indication of size throughout the animation.	*Now imagine* that we could enlarge the fibroblast by 100,000 times. The 16.5 **micron** fibroblast cell would become 165 **centimetres** tall, roughly the height of an average human. Now we can compare some subcellular structures as if a fibroblast were the size of a person.
3	DOLLY and ZOOM into FIBROBLAST CELL, going through the PLASMA MEMBRANE, pausing and turning to look at its thickness. As we focus on the edge of the PLASMA MEMBRANE, the corner of a NEWSPAPER comes into view briefly as a paper-ruffling sound is made.	The plasma membrane is 4 nanometres thick. If a cell were the size of a person, this would be 0.004 centimetres, or half the thickness of newspaper.
4	DOLLY AND ZOOM OUT of the FIBROBLAST CELL, as the PLASMA MEMBRANE blurs and becomes	The **nucleus** (pause) is 10 microns in diameter. In a person-sized cell, it would be

	transparent. The HUMAN FIGURE is seen reading the NEWSPAPER. Focus on the ER and NUCLEUS, with other structures out of focus. Soluble molecules and proteins are invisible for clarity. A BEANBAG CHAIR appears behind the FIGURE, who then sits on it.	1 metre across, about the width of a beanbag chair.
5	Focus on the ER. Sheets of NEWSPAPER cover the overwhelmed FIGURE and BEANBAG CHAIR as more paper-ruffling sounds are heard. ZOOM in to see GOLGI and VESICLES. A BEADED NECKLACE enters frame. ZOOM back to the FIGURE, who is shocked at the necklace that appeared on their neck.	The endomembrane system is difficult to measure because it is a series of membranes that span most of the cell. In a person-sized cell, the rough endoplasmic reticulum would be like wrapping the nucleus in a hundred sheets of newspaper, and the golgi apparatus would be like a stack of newspapers off to one side. Vesicles going to and from the golgi are typically 40-80nm wide, which would be like various sizes of beads between 4 and 8mm wide—all smaller than a pea.
6	PAN TO MITOCHONDRIA, making sure that NUCLEUS is still mostly in shot for comparison. SUB SANDWICHES overwhelm the FIGURE.	Mitochondria vary in size from 1-2 microns. In a person-sized cell, this would be 10-20 centimetres, between the sizes of a hamburger and a sub sandwich. Depending on the cell type, there can be fewer than a hundred to over a thousand mitochondria per cell. Some organisms even have longer mitochondria.
7	EXTREME ZOOM and FOCUS on RIBOSOME and mRNA. The NUCLEUS, ER and FIGURE are seen extremely blurred in the background. A hand holding a BARLEY SEED between its thumb and forefinger enters the frame. When the mRNA is described, a PAPERCLIP moves into frame next to the BARLEY SEED.	Ribosomes are very small, only 30 nanometres across. In a person-sized cell, they would be 3 millimetres, or the size of a barley seed. mRNA, on the other hand, are much longer. An average mRNA strand is about 300 nanometres long, and would be 30 millimetres in a person-sized cell, about the length of a paperclip.
8	DOLLY and ZOOM OUT of FIBROBLAST to reveal the FIGURE holding the items in front of the cell. The FIGURE returns to resting position. The reference objects have stayed off to the side since we	It's easier to get an idea of the **relative** sizes of such tiny structures now that we have seen them in a more familiar scale. If a fibroblast were the size of a person, the plasma membrane would be half as thick

	introduced them earlier. The FIGURE interacts with them when mentioned. The FIBROBLAST jumps back onto the FIGURE's finger shrinking back to its original size.	as newspaper, the nucleus would be the width of a beanbag chair, the endomembrane system would be like newspapers and beads, mitochondria would be like sub sandwiches, mRNA would be as long as paperclips and ribosomes would be as small as barley seeds. (sound less concluding, lol) **But** don't forget, all of these subcellular structures are actually 100,000 times smaller than these everyday objects, (pause) All existing at a scale smaller than a ridge on a fingerprint.
9	FADE OUT to light background.	

PART II: INTERPRETING SCALE IN VISUALIZATIONS

#	Visuals	Voiceover Script
10	PAN down to a FIBROBLAST CELL on a solid white plane. Its organelles shine as light moves over them.	(faster than old recording) Now that you have a basic understanding of the differences in scale between a representative animal cell and its components, let's talk about how these relationships have been and continue to be visualized in illustrations.
11	DEFOCUS so that FIBROBLAST is blurred and lightened. ENTER MICROGRAPH and SIMPLISTIC 3D ILLUSTRATION of the same cell in front of FIBROBLAST. ANIMATE the differences between MICROGRAPH and ILLUSTRATION.	You may wonder: why don't we just use micrographs? While they do show scale accurately, micrographs have noise that makes it difficult to distinguish features, and it's impossible to see some of the smaller structures like ribosomes. An illustration makes clear distinctions between structures, simplifies distracting textures, and exaggerates structures to highlight details that might not be visible otherwise. But this can lead to the problem of misrepresenting scale.
12	HIGHLIGHT RIBOSOMES in the ILLUSTRATION and the MICROGRAPH.	For example, these ribosomes have been enlarged so they are more visible. This makes the illustration technically inaccurate even though it is now clearer. Why is this a problem, you might wonder?
13	MONTAGE of a few illustrations with improperly proportioned nuclei, mitochondria, whole cells, etc with the simplifications being ANIMATED.	When you're constantly exposed to simplifications in representations of cells (pause) such as the size or number of mitochondria and ribosomes, (pause) or the thickness of plasma membranes, (pause) you start to lose your sense of the true sizes of these structures.

		It is important to be aware of whether a visualization is being spatially accurate, or if it is exaggerating the sizes of structures to get a message across.
14	ENTER ILLUSTRATION showing Na/K pumps embedded in a membrane. (labeled) Elements shrink and become more detailed when the answer is revealed. EXIT ILLUSTRATION	Let's take a look at another visualization. Is this image spatially accurate? No, compared to the plasma membrane, the sizes of the membrane proteins and ions have been exaggerated to focus on that process.
15	ENTER ILLUSTRATIONS showing whole ANIMAL CELL, BACTERIA CELL, and YEAST CELL, all at a similar scale. Their organelles are all approximately the right scale for their cells, but the cells themselves are the wrong scale relative to each other. TIMER BAR in the bottom of the screen shrinks over 5 seconds	Now you try. Pause the video and think about the answer. … Is this image spatially accurate?
16		Trick question! The organelles are spatially accurate within each cell, but in comparison to one another, the scales of the bacterium and yeast have been exaggerated for visibility. In **reality**, they should be **this** small—
17	BACTERIA and YEAST images SHRINK so that they are a proper ~ 1/7th and ~ 1/4th the size of the ANIMAL CELL, respectively.	--when compared to animal cells. It seems obvious when you think about it, but the trick is knowing when to think about it in the first place.
18	The BACTERIA and YEAST cells, disappear, leaving only the ANIMAL CELL. Its contents grow or shrink when exaggeration is mentioned.	Now you know that visualizations may exaggerate the scales of things to make the message clearer, and that structures may be shown as different sizes depending on the lesson being taught.
19	All foreground elements disappear, and we focus back to the FIBROBLAST. ZOOM OUT to see more FIBROBLASTS in the environment, and EXTREME ZOOM OUT to view the HUMAN FIGURE.	Now when you encounter new images of cells, you'll be able to think critically about how scale is shown by thinking back to the scale of our fibroblast cell and how its structures can be represented in visualizations.
20	FIGURE FADES OUT to light background.	