It's a Small World After All

Engage:
Cities, factories, even your own home is a network of dependent and independent parts that make the whole function properly. Think of another network that has subunits or parts that depend on each other to make a larger structure or unit work? Now take your example and create a network (similar to the cell phone network, or the ecology network we did earlier this year; these examples are off limits for this activity). You need to provide reasons for a connection before you make the line (edge) that connects the items. You will have 20 minutes to make a drawing of you network with your partner or group. Use a large piece of paper (11"x17") to draw your network. Neatly place your individual subunits, remember we call them nodes (minimum of 10), these are the people, departments of the city, or important parts of the network you chose. Then draw and label your edges (connecting lines, minimum of 1 for each). If you finish early look for more edges (connections) between your nodes and remember they show relationships or interactions.

Explore:
Exchange networks with another group and take 5 minutes to look over their nodes and edges. **On a separate piece of paper propose any nodes you think belong on the other group's network; also note any edges the other group may have missed. Look for nodes and edges your group does not think belong or have sufficient reason for the connection and note them on your paper.** Now look for nodes that have the most connections, we will call these hubs. The hubs are parts of the network that many different other parts depend on, or who rely on lots of other parts for their functions to perform their role in the network. Look at the nodes and count the edges (lines connecting them). Determine how many is average for the nodes on the network and choose 2-4 hubs (nodes with higher than average edges of connections). **List the hubs on your separate piece of paper.** Return the network drawing and your suggestions for nodes and edges and your list of hubs to the group you exchanged with. Look over their suggestions and add them if you agree with their ideas, write a justification if you do not agree with their ideas.
In your lab notebook or the sheet of paper from the other group, answer the following questions with your partner or in your group:

1. How is your network a picture of what is happening in the network, how does it help us understand the big picture of the system?

2. How does this representation fail to show how the individuals and the whole function and in what ways?

3. Does this network change over time or is it always the same; are there changes seasonally, daily, weekly?

4. Why is it necessary to understand what the nodes (individual parts) functions are before understanding how they interact with each other in the system/network?

Explain:
Cell Organelles: The smaller working parts of the cell.

Nucleus: This is where the DNA is kept and RNA is transcribed. RNA is transported out of the nucleus through the nuclear pores. Proteins needed inside the nucleus are transported in through the nuclear pores. The nucleolus is usually visible as a dark spot in the nucleus (note the dark nucleolus in this electron microscope photo of a nucleus), and is the site of ribosome formation.

Ribosomes: Ribosomes are the sites of protein synthesis, where RNA is translated into protein. Protein synthesis is extremely important to cells, and so large numbers of ribosomes are found throughout cells (often numbering in the hundreds or thousands). Ribosomes exist floating freely in the cytoplasm, and also bound to the endoplasmic reticulum (ER). ER bound to ribosomes is called rough ER because the ribosomes appear as black dots on the ER in electron microscope photos, giving the ER a rough texture. Ribosomes have no membrane. Ribosomes disassemble into two subunits when not actively synthesizing protein.

Mitochondria: Mitochondria (singular: mitochondrion) are the sites of aerobic respiration, and generally are the major energy production center in eukaryotes. Mitochondria have two membranes, an inner and an outer... Note the reticulations, or many infoldings, of the inner membrane, these serve to increase the surface area of membrane on which membrane- bound reactions can take place. The existence of this double membrane has led many biologists to theorize that mitochondria are the descendants of some bacteria that were endocytosed (taken in to) by a larger cell billions of years ago, but not digested. This fascinating theory of symbiosis, which might lend an explanation to the development of eukaryotic cells, has additional supporting evidence. Mitochondria have their own DNA and their own ribosomes; and those ribosomes are more similar to bacterial ribosomes than to eukaryotic ribosomes...

Chloroplasts: These organelles are the site of photosynthesis in plants and other photosynthesizing organisms. They also have a double membrane. There is a more complete description of the chloroplast here, in the chapter on photosynthesis...

Endoplasmic Reticulum (ER): The ER is the transport network for molecules targeted for certain modifications and specific final destinations, as opposed to molecules that are destined to float freely in the cytoplasm. There are two types of ER, rough and smooth. Rough ER has ribosomes attached to it, and smooth ER does not.

Golgi apparatus: This organelle modifies molecules and packages them into small membrane bound sacs called vesicles. These sacs can be targeted at various locations in the cell and even to its exterior.

Lysosome: This organelle digests waste materials and food within the cell, breaking down molecules into their base components with strong digestive enzymes. Here we can see an advantage of the compartmentalization of the eukaryotic cell: the cell could not support such destructive enzymes if they were not contained in a membrane-bound lysosome.

Cytosol – This is the liquid found inside cells. In eukaryotes this liquid is separated by cell membranes from the contents of the organelles suspended in the cytosol, such as the mitochondrial matrix inside the mitochondrion. The entire contents of a eukaryotic cell, minus the contents of the cell nucleus, are referred to as the cytoplasm. The cytosol is a complex mixture of substances dissolved in water.

Cytoskeleton – A cellular "scaffolding" or "skeleton" contained within the cytoplasm. The cytoskeleton is present in all cells; it was once thought this structure was unique to eukaryotes, but recent research has identified the prokaryotic cytoskeleton. It is a dynamic structure that maintains cell shape, protects the cell, enables cellular motion, and plays important roles in both intracellular transport (the movement of vesicles and organelles, for example) and cellular division.

Cell Membrane – A two layer structure composed of lipid that surrounds cell and regulates what enters and what exits the cell. The cell membrane (also called the plasma membrane or plasmalemma) is the biological membrane separating the interior of a cell from the outside environment.

Cell Wall – Structure in plant cells and some one celled organisms that is a tough, flexible and sometimes fairly rigid layer that surrounds the cells. It is located outside the cell membrane and provides these cells with structural support and protection, and also acts as a filtering mechanism. A major function of the cell wall is to act as a pressure vessel, preventing over-expansion when water enters the cell.

Vacuole –These sack like structures essentially are enclosed compartments which are filled with water containing inorganic and organic molecules including various enzymes in solution, though in certain cases they may contain solids which have been engulfed.

Information above from http://www.courseworld.com/bio/cell.html and Wikipedia.

Elaborate:
New research is starting to uncover some of the complex interactions between organelles in a single cell. For instance the Golgi apparatus produces the lipid for the cell membrane. Scientists have discovered that in yeast for instance there are interactions that produce a network that is so complex it is hard to even visualize it on a single drawing. (See yeast protein – protein interactions diagram below). Now let's apply the network/systems approach to the cells organelles. While each organelle has its own function, the cell is itself a system of parts that allow the cell to live and perform its functions**. Take an 11"x17" sheet of paper and place the organelles given to you by**

your instructor as nodes on the sheet of paper with properly labeled edges (relationships and interconnections) connecting them. You will use different colors or the different relationships (edges written as arrows) on the network. For structural relationships use yellow, for location relationships use green, for energy relationships use red, and for functions use blue. Place organelles with functions that overlap and depend on each other in a group together, we call these motifs in groups together.

Answer the following questions:

> **5. Is there one color of edge that appears more often than the others, if so what does this us about organelles?**
>
> **6. Is there one organelle (like a keystone species), that the cell cannot function without?**
>
> **7. Compare the size and complexity of the yeast protein – protein network and your organelle network?**

Evaluate:

Option #1 You are applying for a job as an organelle for a cell. Just like in a resume for a job you will present the most important and valued characteristics and attributes. **Write a resume for an organelle of your choice or one given by your instructor. Include the functions, its roll in the cell, and important relationships to other organelles in the cell.**

Option #2 You are the Cell Organelle Resource Officer for the cell (you do all of the hiring and firing). You have been instructed that one of the organelles has to be "down sized" or fired. Choose one organelle that is expendable, and one that the cell cannot lose if it is to survive. **Prepare an oral report to be given to your boss explaining who will make the decision about who gets the axe.**

Option #3 You are an organelle advocate that will tell a committee how your organelle is vital to the function of the cell. Your job is to explain the organelles function and the important relationships and tasks that make it necessary for cellular functioning. In short that the cell cannot effectively function without the organelle you have been given. **Prepare an oral report for a committee deciding what organelle gets the most resources of the cell.**

Option #4 We view the function of a cell at a given moment in time, if you were to look at the inter-workings of a cell over its lifetime there will be interconnections between organelles that are not always well understood or even evident. Scientists who study biological systems have discovered that nodes that interact with each other tend to have relationships that overlap. So for instance if node A interacts with node B and node B interacts with node C, then there is probably an interaction between node A and node C that will become evident if it is not yet known. **If this is the case with our cells how would a malfunction in the metabolism of one organelle of a cell affect the other organelles? Using the mitochondria as your malfunctioning organelle, determine the effects on the other organelles in the cell directly (edges) and indirectly (though other nodes). Write a 1 page conclusion on your lab report or paper explaining the effects on the function of the cell if its mitochondria were to malfunction, with nodes and edges affected.**

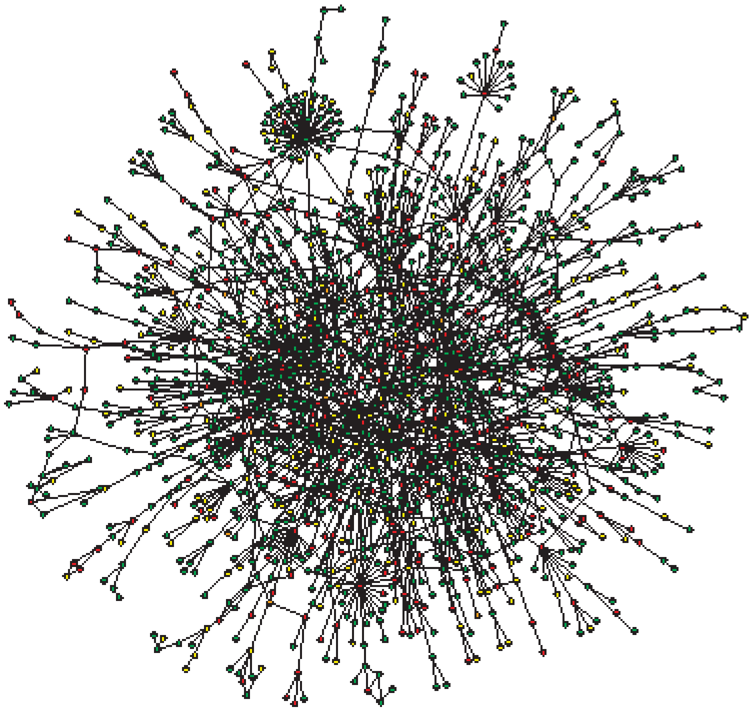

Figure 2 | **Yeast protein interaction network.** A map of protein–protein interactions[18] in *Saccharomyces cerevisiae*, which is based on early yeast two-hybrid measurements[23], illustrates that a few highly connected nodes (which are also known as hubs) hold the network together. The largest cluster, which contains ~78% of all proteins, is shown. The colour of a node indicates the phenotypic effect of removing the corresponding protein (red = lethal, green = non-lethal, orange = slow growth, yellow = unknown). Reproduced with permission from REF. 18 © Macmillan Magazines Ltd.

NETWORK BIOLOGY: UNDERSTANDING THE CELL'S FUNCTIONAL ORGANIZATION.

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http://swift.cmbi.kun.nl/euroschool/lars_papers/Papers/Barabasi_2004_NRG.pdf