

Lesson # 5A Workshop: Complex Networks and Graphs (Adapted from Teaching Engineering's "It's a Connected World")

Subject area / course / grade level: Science Grade 7-10

Summary:

Students are introduced to networks and systems. The students will use this knowledge to create their own model of a neural network (Lesson 5B), use a graph to determine the most important nodes, and map how the nodes impact other regions of the brain (Lesson 5C).

Students should be able to:

- Provide examples of complex networks and formally represent them by graphs.
- Draw a visual representation of a graph and provide a formal description in terms of nodes and edges.
- Identify the degree of a node in a graph and determine the level of importance of each node based on the graph..

Time Needed: 1 Period

Materials:

TEACHER REVIEW: Visit [Teaching Engineering's "It's a Connected World"](#)

Cut & Paste from below:

- Lesson handout 1/student

Vocabulary:

- **Complex network:** A set of individuals (students neurons, molecules, computers, web pages) that interact with each other in a certain fashion
- **Node:** a point of intersection, a connection point
- **Edge:** lines that connect nodes
- **Degree of a node:** The number of edges connecting to the node

WASS: (Middle School):

6-8 LS1-C Multicellular organisms have specialized cells that perform different functions. These cells join together to form tissues that give organs their structure and enable organs to perform specialized functions within organ systems.

6-8 SYSA Any system may be thought of as containing subsystems and as being a subsystem of a larger system.

WASS: (High School):

9-12 INQA Scientists generate and evaluate questions to investigate the natural world.

9-12 SYSB Systems thinking can be especially useful in analyzing complex situations. To be useful, a system needs to be specified as clearly as possible.

NGSS(Middle School):

MS-LS1-d Design and conduct an investigation to gather evidence to support explanations that the body is a system of interacting subsystems composed of groups of cells working to form tissues and organs specialized for particular body functions, and that scientific advances in understanding of those systems have led to improvements in nutrition, health, and medicine.

NGSS (High School):

HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

CCSS:

WHSt.9-12.9 Draw evidence from informational texts to support analysis, reflection and research.

What? Learning about complex networks

How? By building graphs of networks

Why? To build a neuron network in a later lesson.

Differentiation:



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Students will be arranged in groups that include a wide spectrum of learning abilities.
Sentence starters and script templates will be provided to facilitate writing exercise.

ENGAGEMENT (5-10 min) NETWORKS & SYSTEMS

Discuss with the class:

"We all live in a connected world. Many, if not all, of us have cell phones capable of sending signals to nearby cellular towers, which can be bounced all over the world to potentially reach other people with phones. Likewise, we have access to computers, which can connect to other computers all over the world using the internet. While these networked systems of interconnected components are triumphs of modern engineering, nature has been producing large and complex networks for millions of years."

- Can anyone think of other examples of complex networks?

Network	Nodes	Edges
biochemical	molecules	chemical reactions
neural	neurons	synaptic connections
epidemiological	healthy, infected individuals	infectious contacts
world wide web	web pages	hyperlinks
trophic	predators, prey	predation interactions
power grid	electrical generators, end users	power lines, substations, transformers
collaborative	scientists, engineers	collaborations
social	people	friendships
internet	computers	routers, ethernet cables

EXPLORATION (30 min) INVESTIGATING NETWORKS

- Use the templates below to cut & paste a teacher created worksheet or PPT.
- Make sure students understand vocab terms before completing worksheet.

Node: a point of intersection, a connection point

Edge: lines that connect nodes

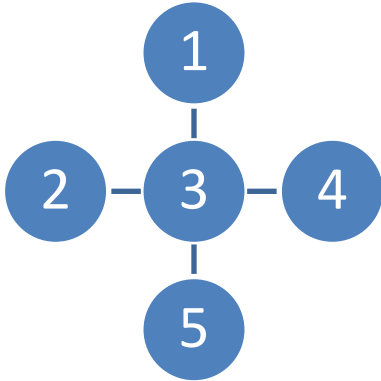
Degree of a node: The number of edges connecting to the node



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CUT & PASTE

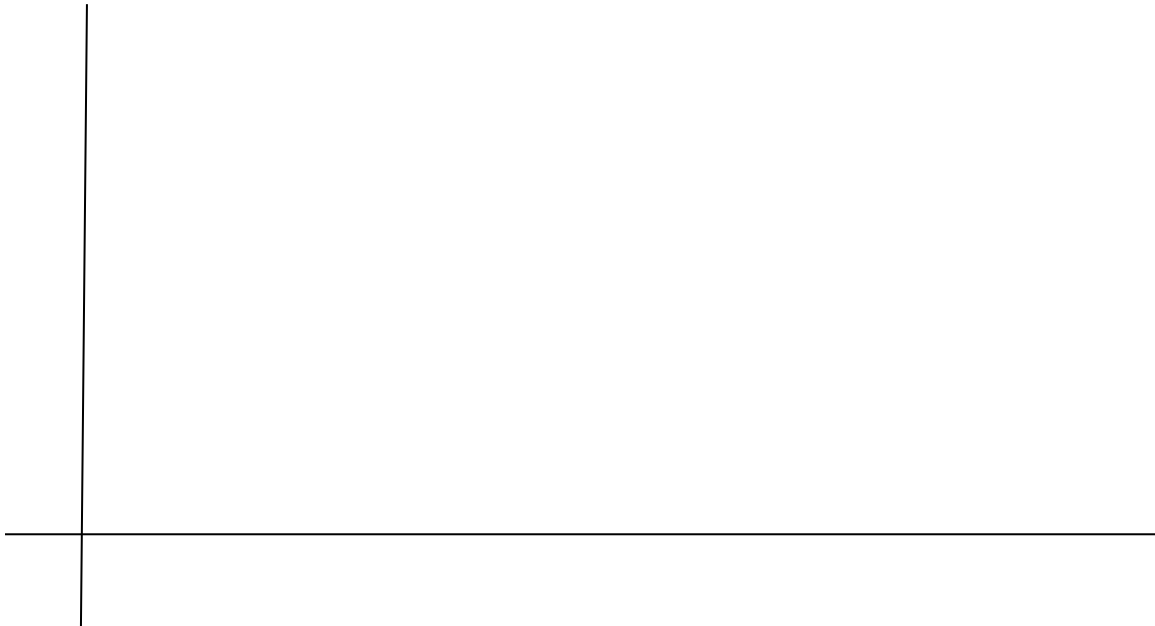
Example 1:



Node	# of Edges

CUT & PASTE

Draw and label a histogram of the Node vs edges. Which is the dependent variable? Which is the independent variable? (Remember, the dependent variable goes on the y-axis and the independent variable goes on the x-axis.)



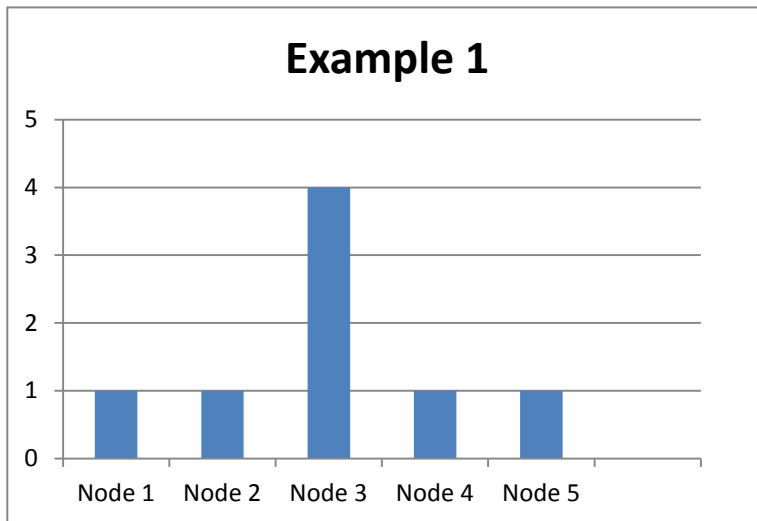
Questions:



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1. How many nodes are there in the diagram?
2. Which node(s) has the highest degree (degree= # of edges)?
3. Which node(s) has the lowest degree?

Graph:

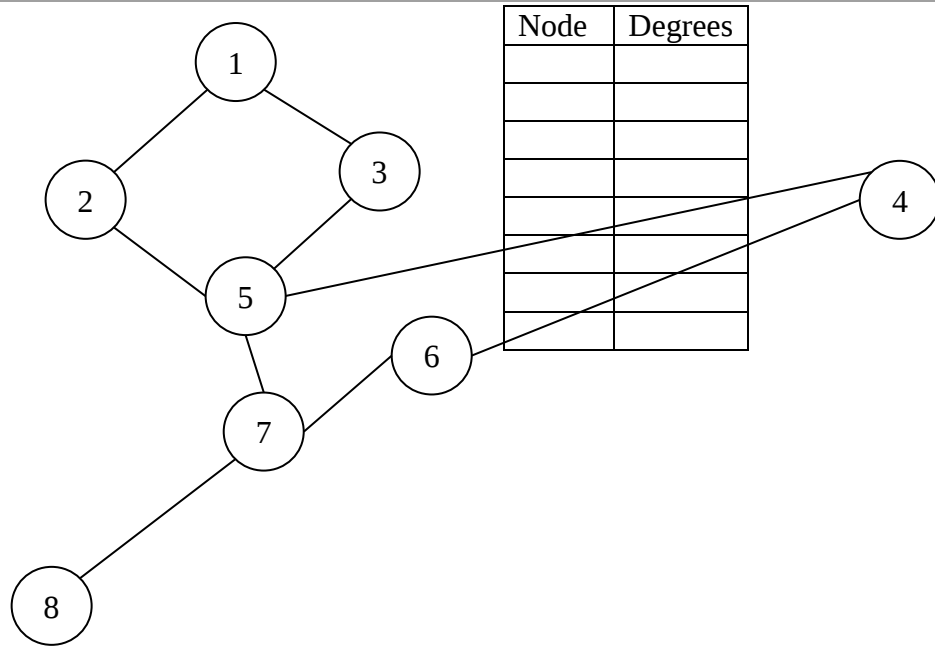


Node	# of Edges
1	1
2	1
3	4
4	1
5	1

Example 2



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Draw and label a histogram of the Node vs edges.



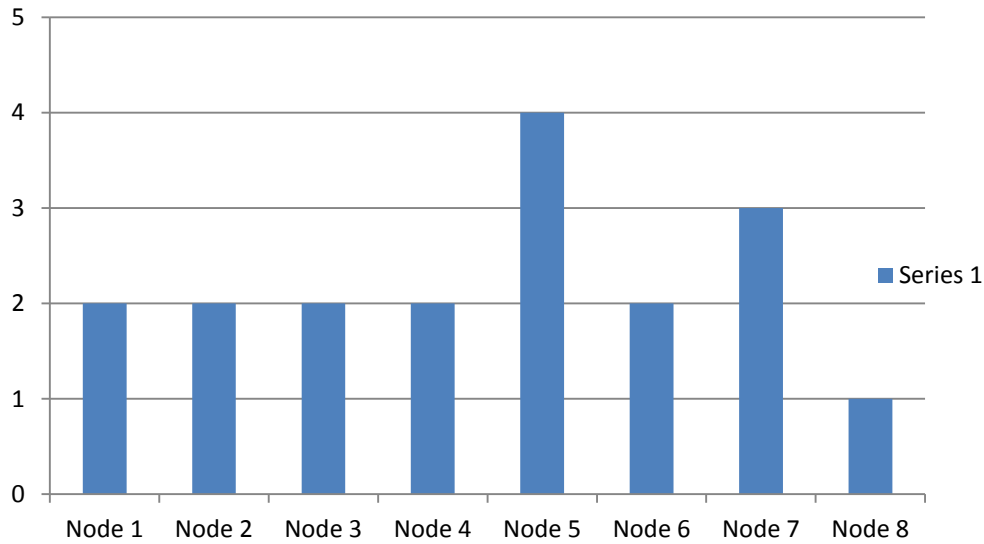
Questions:

1. Which node is the most important? Why?
2. Which node is the second most important? Why?
3. Which node is the least important? Why?



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Example 2



Node	# of Edges
1	2
2	2
3	2
4	2
5	4
6	2
7	3
8	1

Example 3:

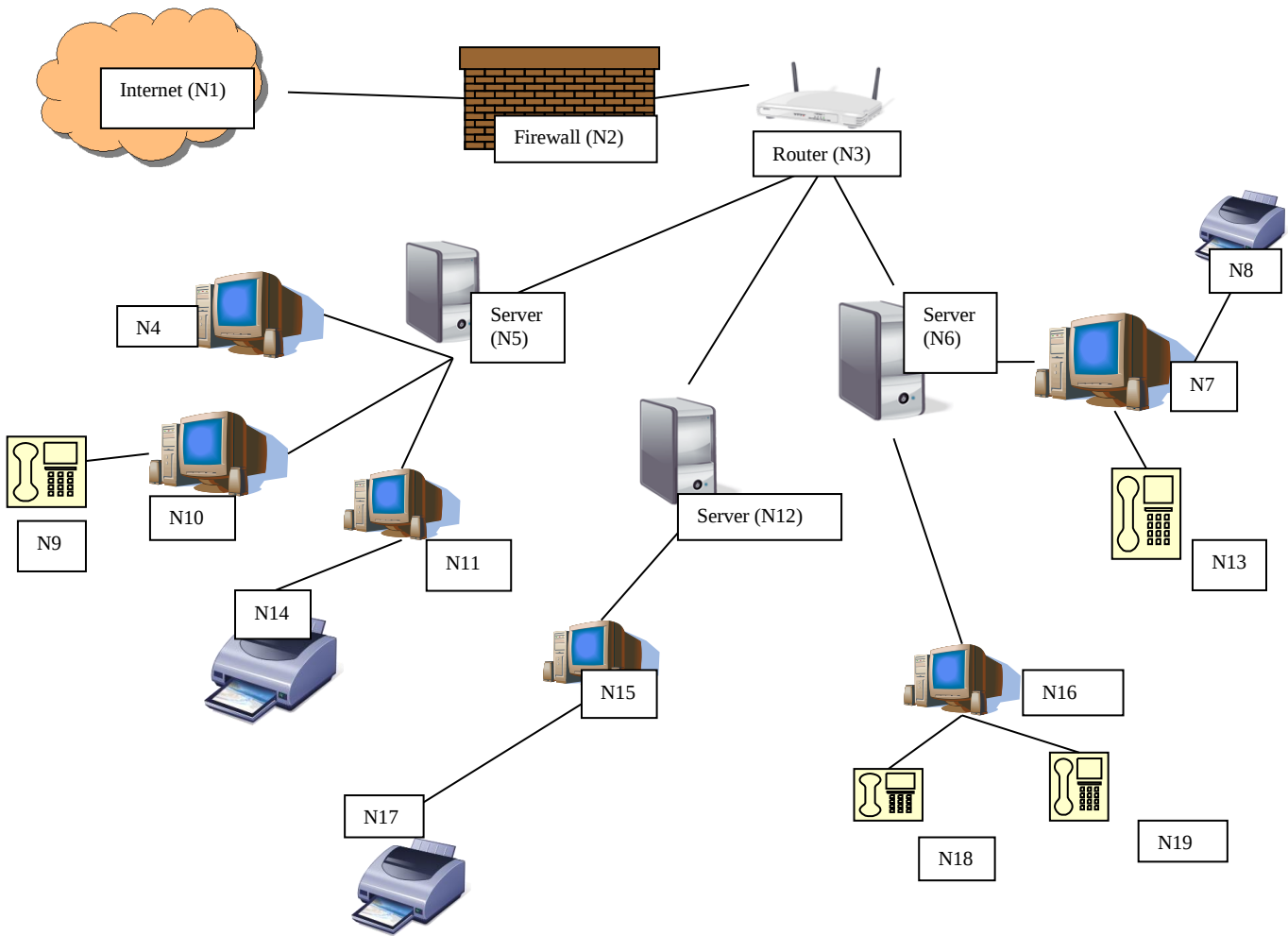
Computer networks are similarly connected. Complete the table below for the given office diagram:

Node	Degree	Node	Degree
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10			



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Questions:

What is the most important part(s) of this network? Explain your answer.

1. What are the least important part(s) of this network? Explain your answer.
2. Suppose Server N6 stops working. What effect will this have on computer N16? On Printer N14? Explain.

Extension:

3. Draw an edge between Server N12 and computer N16. If Server N6 stops working, what impact will the new connection have on Computer N16?

EXPLANATION (On Going)

Educators will rove the room to check for understanding.

ELABORATION (On Going)

To be completed in lessons 5B & 5C.

EVALUATION

The worksheet will be the assessment.



Lesson # 5B & 5C Building a 3D Neural Network

Subject area / course / grade level: Science Grades 7-10

Summary:

Students will build a class model to analyze the complex neural network in one region of the brain (Lesson 5B). Students will diagram the Nodes and Degrees in their class model. Students will determine the most important nodes in the class model. Students will integrate their class model with other classes to construct a 3D model of the entire brain (Lesson 5C). Students will analyze the impact of a TBI (and/or treatments e.g. “devices”) in one region will impact other regions of the brain.

Time Needed: 2-3 days

Materials:

3D Brain Box: One per class period.

This box is constructed of PVC pipe and includes 3 mesh layers whereupon students will place their small neuron models.

- Craft materials to construct 24 small neurons per class. Neuron models should have axons of one color and dendrites of a different color. (See images)
**We planned for 100 neurons total to be divided over 4 classes. We used pipe cleaners, macaroni noodles, body scrubbers cut up, floral wire cut into small pieces (@ 4/neuron), bubble wrap to be used as synapses, w/small rare earth magnets inside the bubble wrap to help the synapse of one neuron be attracted to the dendrite of another.*
- Labeling tape: Each neuron requires unique node identifiers
- Scaled Traumatic Brain Injury examples (e.g. Phineas Gage tamping rod)
- Scaled TBI solutions (E.g. “array device”)

WASS: (Middle School):

6-8 LS1-C Multicellular organisms have specialized cells that perform different functions. These cells join together to form tissues that give organs their structure and enable organs to perform specialized functions within organ systems.

6-8 SYSA Any system may be thought of as containing subsystems and as being a subsystem of a larger system.

WASS: (High School):

9-12 SYSB Systems thinking can be especially useful in analyzing complex situations. To be useful, a system needs to be specified as clearly as possible.

9-12 APPA Science affects society and cultures by influencing the way many people think about themselves, others, and the environment. Society also affects science by its prevailing views about what is important to study and by deciding what research will be funded.

9-12 APPD The ability to solve problems is greatly enhanced by use of mathematics and information technologies.

NGSS(Middle School):

MS-LS1-d Design and conduct an investigation to gather evidence to support explanations that the body is a system of interacting subsystems composed of groups of cells working to form tissues and organs specialized for particular body functions, and that scientific advances in understanding of those systems have led to improvements in nutrition, health, and medicine.

NGSS (High School):

HS-LS1-1 Construct an explanation based on evidence for how (the structure of neurons determines how the brain functions... to carry out the essential functions of life through systems of specialized cells.

CCSS:

WHST 9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific experiments, or technical processes.

What? Building a 3D Neural Network Model

How? As groups

Why? To analyze how different parts of the brain interact with one another



Lesson # 5B & 5C Building a 3D Neural Network

Differentiation:

Students will be arranged in groups that include a wide spectrum of learning abilities. Sentence starters and script templates will be provided to facilitate writing exercise.

ENGAGEMENT (15 min) Understanding Phineas

- Students will revisit the Phineas Gage accident by watching the video: [Phineas Gage](#) (2:16)
- Students will answer the following questions in their science journal:
 - What was Phineas like before the accident?
 - What stayed the same for Phineas after the accident?
 - What changed?
 - What regions of his brain were most affected by the accident? (left forebrain)
 - What information did his injury provide to neuroscientists?

EXPLORATION (35 min) Lesson 5B: Making Neurons

- Have students label neurons using labeling tape: Each neuron requires unique node identifiers. (Example)

Period	Lobe	Color	Neuron Letter (node #)
1	Parietal	Orange	A (1-15)
2	Frontal	Yellow	B (1-15)
3	Occipital	Purple	C (1-15)
4	Temporal	Pink	D (1-15)
5 (if necessary)	Cerebellum	Green	E (1-15)
6 (if necessary)	Brain Stem	Red	F (1-15)

Each group will build 3-4 small neurons. Place on the Brain Box as follows:

- When the first neuron is done (from any group), place it anywhere on level one of the Brain Box.
- When the second neuron is done, place it anywhere on the second level of the Brain Box.
- When the third neuron is done, place it anywhere on the third level of the Brain Box.
- Continue to alternate the positioning of the neurons as they are completed in this manner. In the third round, (about 6 neurons are on the Brain Box), students should also connect dendrites from one neuron to axons of nearby neurons.

ENGAGEMENT (10 min) DAY 2 / Lesson 5C: Next Steps

- Start lesson with engaging questions to revisit previous day's work.
- Questions should be specific to the lobe built in each class.
 - What actions are controlled in this region of the brain?
 - How do the neurons communicate with each other?
 - Do the neurons touch each other to communicate?
 - Which neuron(s) are the most important? Explain?

ELABORATION (15-20 min) Connecting the Regions

- Have students watch video clip of [Tampering Rod path](#) (0:05)
- Students will add connecting neurons from the most important nodes to adjacent lobes (from alternate classes), and answer questions.

ELABORATION (10-15 min)

INSTRUCT

- Sketch a diagram of the neural network in your journal. Correctly label each of the nodes in your diagram.
- Label your diagram and identify the primary function of the lobe. (Teacher will approve each sketch before moving forward.)



Lesson # 5B & 5C Building a 3D Neural Network

3. Identify the most important nodes in your neural network.

Answer the following questions:

1. Identify the most important nodes in the other regions of the brain.
2. Use the completed Brain Box Model to explain the difference in Phineas Gage after the accident.
3. How might damage in one region affect other connected regions?
4. Are there alternate pathways for Action potentials to travel?
5. What is an advantage of these alternate pathways?

*ALTERNATIVES/EXTENSIONS:

- Incorporate Excitatory vs Inhibitory neurons

OR

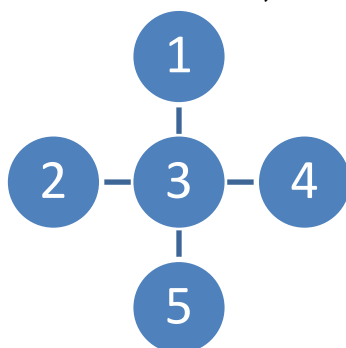
- S.I.R. model of neural propagation: (See below)

❖ S – Susceptible to Firing

❖ I – In process of Firing

❖ R – Recovering (i.e. cannot fire while recovering)

Choose a neuron (in a specific region) with a single edge as a start. At time, $t=0$, Starting neuron is I, in process of firing. All other neurons are S, susceptible to firing.



For Example:

Node	Time $t=0$	$t=1$ second	$t = 2$ s	$t = 3$ s	$t = 4$ s	$t = 5$ s	$t = 6$ S
1	S	I	R	S	S	S	S
2	S	S	S	I	I	R	S
3	S	S	I	R	S	S	S
4	S	S	S	I	I	R	S
5	S	S	S	I	I	R	S

Extension question:

1. If node three were excited first, which neurons would be excited next?
2. Would an Action Potential fire if a second impulse excited Node 3 at time, 3s? Explain?

EVALUATION (Ongoing)

Student journals should be used to evaluate understanding.

