A PBL APPROACH TO KREBS CYCLE AND ELECTRON TRANSPORT - SBI4U

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Students are guided through a case study used to introduce the IOU inquiry process (making **I**nferences from **O**bservations based on **U**nderstanding) used in Problem Based Learning (PBL). Opportunity for formative assessment of both process skills and content knowledge is provided following the first case study. Once the skills and processes are developed, students move on to a small group case study using the same process to increase the depth of understanding. Using this process, students will develop their skills in observation, inference, questioning, research, and data analysis through case studies freely available from the internet. During the process, students should develop enough depth of understanding to be successful on a traditional paper/pencil unit test in addition to the case study evaluation.

This lesson incorporates an approach to teaching through interrupted case studies. Students are provided with an opportunity to make meaningful connections to a simulated real-world problem using critical thinking skills to incorporate previous knowledge, ask questions, and seek out new understanding in a collaborative environment. The outcome is that students support their final inference with accurate understandings. Regardless of the final explanation, if the critical thinking process leads to supporting a reasonable inference, the student has still demonstrated achievement of the expectations.

Course Code: SBI 4U – Grade 12 Biology, University Preparation

Strand(s) and Unit(s):

Main Focus

Unit C – Metabolic Processes

Integrated Concepts and Skills

Unit A – Scientific Investigation Skills and Career Exploration

Unit B – Biochemistry

INQUIRY FOCUS

How does the human body produce energy from food?

Why are enzymes important to metabolic processes?

What can we learn/infer from patient symptoms and blood chemistry data?

TIMELINE

Assuming 75 min of instructional time/class and prior knowledge in basic biochemistry (functional groups and energy molecules), roles of biochemical enzymes, and the reactions in glycolysis

3-5 classes for formative PBL lesson,

2-3 classes for the independent summative portion.

> *Note: The overall time required will depend on students' background knowledge, skills set, level of interest, and additional time required to complete student work.*

BIG IDEAS

Metabolic Processes

- All metabolic processes involve chemical changes and energy conversions.

Biochemistry

- Biological molecules and their chemical properties affect cellular processes and biochemical reactions.

OVERALL EXPECTATIONS

The sheer volume of expectations covered is included to show how powerful this style of teaching can be in helping students develop a deep understanding of most of these expectations in as little as 10 classes!

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

B2. investigate the chemical structures, functions, and chemical properties of biological molecules involved in some common cellular processes and biochemical reactions;

B3. demonstrate an understanding of the structures and functions of biological molecules, and the biochemical reactions required to maintain normal cellular function;

C1. analyse the role of metabolic processes in the functioning of biotic and abiotic systems, and evaluate the importance of an understanding of these processes and related technologies to personal choices made in everyday life;[1]

C2. investigate the products of metabolic processes such as cellular respiration and photosynthesis;

C3. demonstrate an understanding of the chemical changes and energy conversions that occur in metabolic processes.

[1] *depends on the case(s) available or created for use.*

SPECIFIC EXPECTATIONS[2]

Focus

C1.2 assess the relevance, to their personal lives and to the community, of an understanding of cell biology and related technologies [AI, C]

C2.1 use appropriate terminology related to metabolism, including, but not limited to: energy carriers, glycolysis, Krebs Cycle, electron transport chain, ATP synthase, oxidative phosphorylation, chemiosmosis, proton pump, photolysis, Calvin cycle, light and dark reactions, and cyclic and noncyclic phosphorylation [C]

C3.1 explain the chemical changes and energy conversions associated with the processes of aerobic and anaerobic cellular respiration

Supplemental

B2.1 use appropriate terminology related to biochemistry, including, but not limited to: active and passive transport, covalent and ionic bond, allosteric site, substrate, substrate-enzyme complex, and inhibition [C]

B3.3 identify common functional groups within biological molecules (e.g., hydroxyl, carbonyl, carboxyl, amino, phosphate), and explain how they contribute to the function of each molecule

B3.5 identify and describe the four main types of biochemical reactions (oxidation-reduction [redox], hydrolysis, condensation, and neutralization)

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

[2]*The actual expectations covered will vary based on the student questions. These are the specific expectations that **could** be covered using this method. Professional judgement and student interest will ultimately narrow the focus of the PBL investigation as the goal of the process is to cover the **overall** expectation, and may not necessarily use the specific examples provided by the curriculum documents. The goal of the facilitator is to guide students towards those concepts that are deemed most important.*

KEY CONCEPTS

Pyruvate oxidation, Krebs Cycle, (electron transport – see note in next section), biochemical enzymes, observation, inference, data analysis, research

PRIOR SKILL SETS

Introductory methods will be provided for the inquiry strategy used, but students will be at a distinct advantage if they have already mastered:

- Questioning (e.g., higher order questions based on Bloom's Taxonomy)
- Observation
- Inference

- Data analysis (interpreting tables and/or graphs)

PRIOR KNOWLEDGE

Students will need a **basic understanding** (e.g., recognition) or background readings of:

- the structure/function relationship of the major functional groups (hydroxyl, carboxyl, carbonyl, amino, sulfhydryl, phosphate)
- ATP, NADH
- the major enzyme groups (kinase, carboxylase/decarboxylase, mutase, isomerase)
- factors affecting enzyme activity
- entropy and chemical energy conversions
- chemical changes in the process of glycolysis[3]

[3]Note: It is very important that students can follow the molecular changes in the process of Glycolysis, not necessarily that they memorize every single molecule, but given an overview of the process, they can recognize/explain how each molecule is changed, the type of enzyme, and how the enzyme acts (generally). In the PBL activity that will be described, students will be required to interpret pyruvate oxidation and Krebs cycle (and depending on their questions, oxidative phosphorylation) independently with the teacher acting as a facilitator.

MATERIALS AND EQUIPMENT

- Presentation file with IOU Squid Organizer and Observe/Infer Chart and Handouts (https://docs.google.com/presentation/d/1M3y1KDvwaJIzzMmWrEI62y90l44VoqTdpcfhLOAXjWI/edit?usp=sharing (https://docs.google.com/presentation/d/1M3y1KDvwaJIzzMmWrEI62y90l44VoqTdpcfhLOAXjWI/edit?usp=sharing))
- Case study **(Handout 2)**(The one provided is modified from The National Center for Case Study Teaching in Science; the original can be viewed here http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=482&id=482 (http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=482&id=482))
- 11” X 17” IOU “squid” Foldable Organizer **(Handout 3)**
- Textbooks
- Internet connection (Mobile phones, tablet computers, laptops, or classroom computers as available)
- Teacher demonstration IOU chart and/or electronic version (see presentation file above)
- 2 colours of small (1.5” X 2”) sticky notes – enough for class set (For the purposes of this document, I will be using green and pink sticky notes.)
- 2 colours of large sticky notes (same colours as small) – for teacher demonstration
- Chart paper
- Markers
- Pre-prepared lessons on concepts you anticipate students will struggle with (I recommend electron transport/chemiosmosis, determining total ATP production [from $FADH_2$ and NADH] as starting points.)

Handout Overview

Handout 1	*Handout 2*	*Handout 3*	*Handout 4*	*Handout 5*
Observe/Infer Chart	Case Study used by students (and teacher)	IOU “Squid” organizer	Assessment Checklist	Sample Rubric

SAFETY

No safety precautions.

INSTRUCTIONAL PLANNING AND DELIVERY AND ASSESSMENT OPPORTUNITIES

Background Skills – Observation and Inference (10-15 min)

> *This can be done earlier in the unit, before prior knowledge to engage students with what they are actually studying! It can be used as a start-up activity for a few days in a row until most students are clear about the difference between observation and inference. If students have developed these skills in grades 9-11, a quick refresher is all that is necessary.*

1. Distribute the two colours of small sticky notes so they are available to each student. (Depending on familiarity with the process, you may wish to distribute the colours at separate times.)
2. Provide students with a copy of the Observe/Infer handout (Handout 1 or Presentation link). (Alternatively to save costs, you could simply have students create a T-chart on their own note paper.)
3. Instruct students to use only the green sticky notes. Using separate sticky notes for **each** observation, instruct students to *individually* record observations about the image provided and stick them in the observation column of their chart/organizer. (See accompanying presentation document.)
4. Have students work with their elbow partner (neighbour) and have them take turns sharing (*Think-pair-share).*

> - For more information on Think-pair-share, visit http://www.readwritethink.org/professional-development/strategy-guides/using-think-pair-share-30626.html (http://www.readwritethink.org/professional-development/strategy-guides/using-think-pair-share-30626.html)

5. Using a method of your choice (numbered heads, volunteer, etc.), collect observations from various people in the room.

> - For more information on numbered heads, visit https://teaching-strategies.wikispaces.com/Numbered+Heads (https://teaching-strategies.wikispaces.com/Numbered+Heads)

6. As students share, record actual **observations** (direct description using senses) on green sticky notes and attach them to the observation side of the demonstration chart. Record **inferences** (guesses, hypotheses based on observations) on pink sticky notes and attach them to the infer side of the demonstration chart.
7. Once complete, have students identify the characteristics of observations, and inferences.
8. I like to see if students can use the observations to determine what the image actually is. Use the observation terms as search terms (e.g. in Google or Bing). It is best not to tell them what the image is because the whole idea is they are using their observations and understandings to support the outcome, not find one "correct" answer. You could also have the class choose the search terms and perform the search as a class using a computer/data projector. You will find that students will do this automatically and have found the image on their mobile devices before you even suggest it.

Exemplar:

A model of how this might turn out can be found at the link below:

http://linoit.com/users/rgdunne/canvases/Metabolism%20-%20Observe%20and%20Infer (http://linoit.com/users/rgdunne/canvases/Metabolism%20-%20Observe%20and%20Infer)

Part 1 – Class (formative) Case Study

1. Begin with the assessment in mind: students will analyze the case and provide a summary in the form of a “coroner’s report” that answers the questions students develop while researching the case (handout 4). Some may be uncomfortable with the idea of a coroner’s report so you could change it to a “Doctor’s report” instead. Handout 5 is a generic rubric that can be used for all PBL activities using this process. It can also be easily modified for specific expectations and/or marking preferences, if required.

> *It is highly recommended that the names used in the case study are changed and students are not provided with the links as (unfortunately) some instructors have published “answer keys” on the internet.*

2. Prepare the case study by printing out Handout 4 and cutting it into the three parts.
3. Have students move into groups of 3-4. In the past, I have found that grouping similar level students is advantageous as it eliminates the reliance on one student and increases interdependence.
4. Distribute copies of the IOU handout. To create the foldable, orient the page landscape (so the text is the correct way up) and fold it in half so that the observe and infer boxes are on top of one another. Next, fold one side back over towards the crease to make the observe/infer chart.
5. Distribute the first section of the case study. Have students record observations on the green stickies and place them appropriately. They may start to formulate inferences and questions which can be recorded on the pink stickies and placed on the organizer.

> *Some students will prefer to record directly in the table. I would encourage them to use the stickies for this assignment, and let them diverge the next time you use this foldable/process so that they can see how the process works and shows their thinking processes.*

6. Again, collect observations from the whole class and record them on the master chart using appropriate coloured sticky notes. Alternatively, you could have students come up and record them.
7. Have students work individually to come up with three questions they have about the information they have been given (including questions they may have already recorded). These questions are then shared one at a time with their group members.
8. Distribute chart paper and markers to each group. At the top of each page, have students write the words “I Need To Understand…” (aka INTUs) and record the group’s questions in the space below.
9. Post the recorded questions and have students observe the questions posed by the class to note similarities and differences in questions, and the quality of the questions. Students can then return to their groups and refine their questions.

> *This is usually where I discuss the quality of questions. E.g., “what is the problem?” is both too broad and too complex at this point, whereas “what does dmyelinating mean?” is a good question at the knowledge/understanding level. I use stems from Bloom’s Taxonomy to help students devise questions that will lead to better research and understanding of the problem.*

10. Collect the refined questions and sort/select those that connect directly to the concepts you hope to cover (this may need to be done daily throughout the process as students will pose new and/or more complex questions). These now represent the INTUs or Learning Goals for the topic.

11. As students answer the INTUs, observation stickies are moved from the chart to the **observation** circles on the squid diagrams. The **understandings** that are developed are then written on the lines or on larger stickies that are associated with the lines. Once students think they have an idea of the underlying cause, they record it on a pink sticky and place that on the **infer** diamond shape. An example anchor chart is provided below (figure 1) as well as a completed "student" example (figure 2). You choose when to provide each group with additional information as the groups ask questions that relate to bloodwork, genetic analysis, etc.

Figure 1 *– anchor chart used to remind students about the process using the "squid" organizer to make* ***Inferences*** *from* ***Observations*** *based on their researched/learned* ***Understanding.***

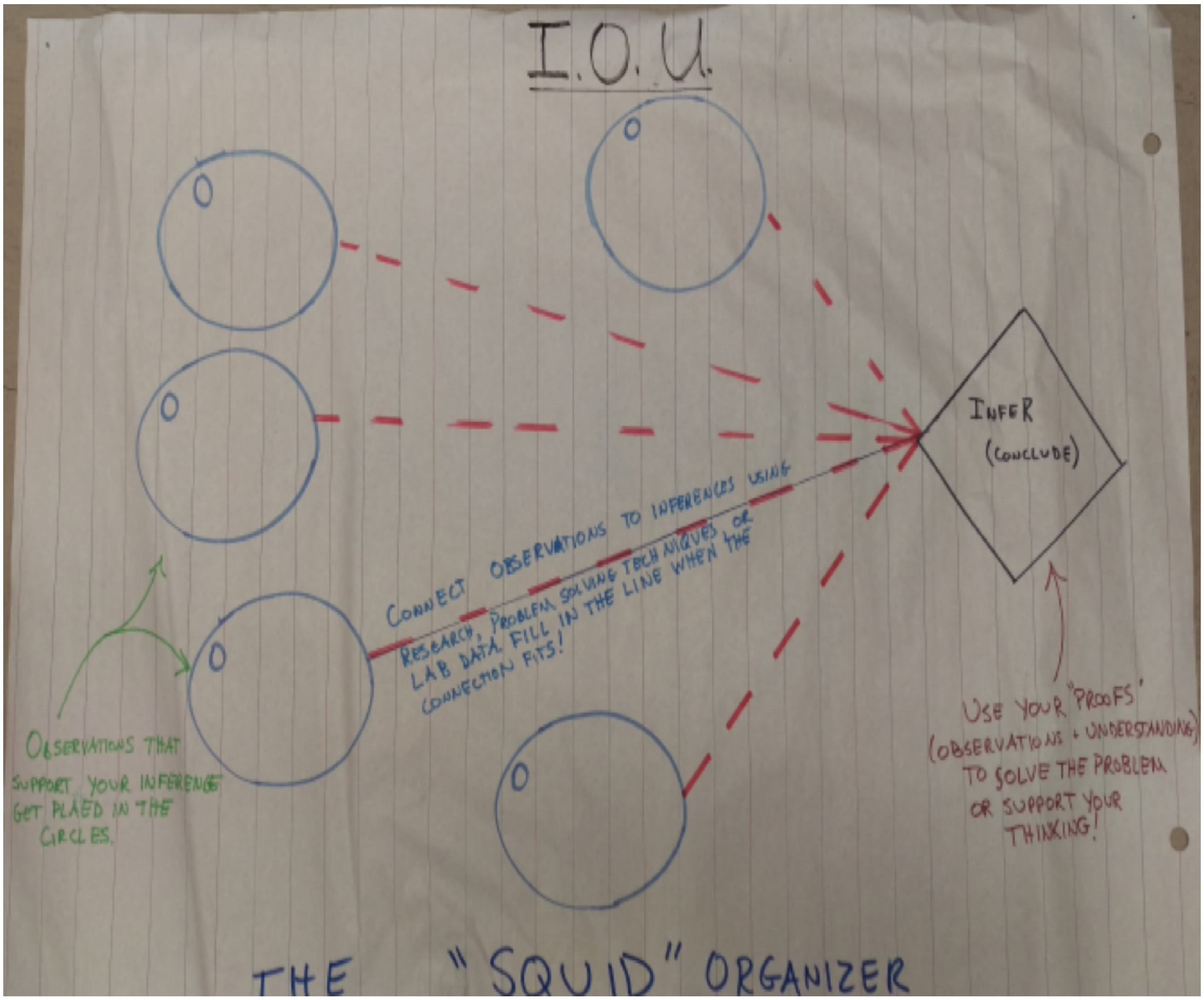
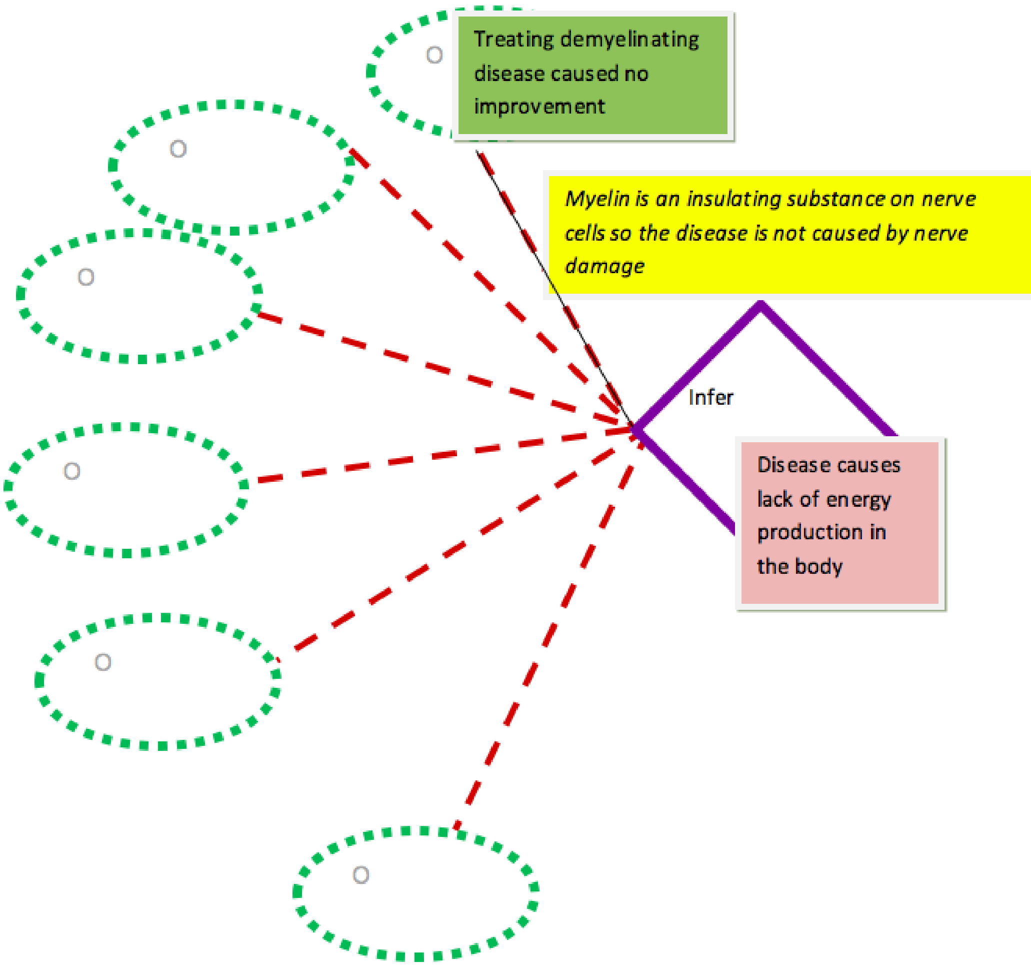


Figure 2 *– example "squid" organizer completion. In this case, the student would continue supporting observations that refine their understanding of the problem. Because the understanding is complete, the dotted line is physically connected to represent a completed connection.*



12. Over the next class/few classes, students use the INTU (*I Need To Understand)* questions as their basis for research and understanding. Acting as facilitator, you can choose which information to provide at what time based on the questions students ask and the confusion/complexities faced by the students.

Some students will need to be coaxed/guided towards different concepts. Some groups will ask about blood work right away, some will wonder how to get more information. Attempt to inspire questions by asking leading questions. Based on personal observation and assessment data, students tend to develop a deeper understanding and retain the knowledge if they come to it themselves, or at least have a reason to obtain the knowledge/understanding. By developing the questioning/research skills, they will be able to repeat the process and are able to work more independently to research and analyse information.

Part 2 – Summative Assessment of Process Skills and Extension into Oxidative Phosphorylation

1. Groups are provided with one of two options related to the same concepts and this time work independently to determine a solution:

The Mystery of Seven Deaths - http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=431&id=431 (http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=431&id=431)

Flea Dip - http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3203684/ (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3203684/)

> *Again, it is highly recommended to re-work the "question/answer" format of these cases and have students work through the process as in the first case. It will likely be necessary to interject at some point with an interactive lesson on oxidative phosphorylation and an example of how to calculate the total ATP from the processes. Students will then determine what part of the process was not working using the data that you provide for them as part of the case study.*

2. Students are then assessed similarly to the first assignment (depending on how the case studies are re-worked).

RELATED BACKGROUND RESOURCES AND LINKS

Baines, A. T., McVey, M., Rybarczyk, B., Thompson, J. T., & Wilkins, H. R. (2004). Mystery of the Toxic Flea Dip: An Interactive Approach to Teaching Aerobic Cellular Respiration. *Cell Biology Education*, *3*(1), 62–68. doi:10.1187/cbe.03-06-0022

Gazdik, M.A. (2010). The Mystery of the Seven Deaths A Case Study in Cellular Respiration. *Retrieved from http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=431&id=431* (http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=431&id=431) *. National Center for Case Study Teaching in Science, University at Buffalo.*

Gunnerson, K.J. (2011). Lactic Acidosis. *Retrieved from* http://emedicine.medscape.com/article/167027-overview (http://emedicine.medscape.com/article/167027-overview). WebMD. LLC.

Kagan, S. n.d. Numbered Heads. *Retrieved from* https://teaching-strategies.wikispaces.com/Numbered+Heads (https://teaching-strategies.wikispaces.com/Numbered+Heads) on August 31, 2015. Tangient LLC.

Knabb, M. (2010). Why is Patrick Paralyzed? *Retrieved from* http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=482&id=482 (http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=482&id=482). National Center for Case Study Teaching in Science, University at Buffalo.

Simon, C.A. n.d. Using the Think-Pair-Share Technique. *Retrieved from* http://www.readwritethink.org/professional-development/strategy-guides/using-think-pair-share-30626.html (http://www.readwritethink.org/professional-development/strategy-guides/using-think-pair-share-30626.html) on August 31, 2015. ILA/NCTE.

University of Iowa. (2011). University of Iowa Department of Pathology Laboratory Services Handbook. *Retrieved from* http://www.healthcare.uiowa.edu/path_handbook/handbook/test2339.html (http://www.healthcare.uiowa.edu/path_handbook/handbook/test2339.html).

Smarter Science organizers (Observe Infer model) developed by the Thames Valley DSB Science task force and other Smarter Science organizers (Experimental Design) are available at https://sites.google.com/site/studentcentredinquiry/posters-handouts (https://sites.google.com/site/studentcentredinquiry/posters-handouts)

Copyright and acceptable use policies for Case Studies from the National Center for Case Study Teaching in Science can be found at http://sciencecases.lib.buffalo.edu/cs/collection/uses/index.asp (http://sciencecases.lib.buffalo.edu/cs/collection/uses/index.asp)

Future Opportunities/Extensions

- Classroom visit from a city coroner to discuss their job
- Additional case studies using the same PBL format
- Investigate photosynthesis and similar interactions with photosynthetic pathways; have students work backwards to create a case study.
- Debate the use of insecticides that disrupt electron transport or metabolic enzymes
- Research other metabolic diseases and determine the effect on ATP production

WATCH THE VIDEO
04:37 min

(//www.youtube.com/embed/0uexgfhMLk8?width=800&height=450&iframe=true)

RESOURCES

- Presentation File (https://docs.google.com/presentation/d/1M3y1KDvwaJIzzMmWrEI62y90l44VoqTdpcfhLOAXjWI/edit)
- Mystery of Seven Deaths (http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp)
- Lactic Acidosis (http://emedicine.medscape.com/article/167027-overview)
- Numbered Heads (https://teaching-strategies.wikispaces.com/Numbered+Heads)
- Why is Patrick Paralyzed? (http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp)
- Think-Pair-Share (http://www.readwritethink.org/professional-development/strategy-guides/using-think-pair-share-30626.html)
- Pathology Laboratory Services Handbook (http://www.healthcare.uiowa.edu/path_handbook/handbook/test2339.html)
- Smarter Science Organizers (https://sites.google.com/site/studentcentredinquiry/posters-handouts)
- Copyright and Acceptable Use Policy information for the Case Studies (http://sciencecases.lib.buffalo.edu/cs/collection/uses/index.asp)

gr 12 metabolic processes entire package with handouts.docx (https://connex.stao.ca/sites/default/files/gr_12_metabolic_processes_entire_package_with_handouts.docx)

ELEMENT

Inquiry (/expert-elements/inquiry)

(/classroom-catalysts) RETURN TO CATALYSTS (/classroom-catalysts)