Bringing Escape Room Concepts to Pathophysiology Case Studies

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Abstract

Escape rooms are physical games set in fictional settings where participants work together to find hidden objects, complete tasks, and solve puzzles to escape the room in a limited amount of time. Escape rooms are problem-based, collaborative, and require interaction with physical aspects of the game. Portable escape boxes are games developed using escape room concepts but can be taken into the classroom. Instead of escaping a room, students work together to complete tasks to get deeper into the escape box. The examination of pathophysiology case studies is well suited for the use of escape boxes since they are inherently problem-based. Using escape boxes is a natural progression to further problem and team-based learning in the use of case studies in pathophysiology and medical education. This article explores the development of an escape box, presents the challenges and narrative of the game and discusses the lessons learned during the process. doi: 10.21692/haps.2017.015

Key Words: pathophysiology, medical education, escape rooms, active learning, PBL

Introduction

Escape rooms are "live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal, usually escaping from the room, in a limited amount of time" (Nicholson 2015). If participants are successful they escape the game and win the challenge. Escape rooms are collaborative, problem-based, time-constrained and active, which are often things that educators want to create in their classroom to promote learning (Bergman *et al.* 2013, Freeman *et al.* 2014, Schmidt *et al.* 2011). Escape games put participants in direct contact with each other and require them to collaborate in the physical world instead of having each participant lost in their own screen; therefore, they are excellent activities to enhance an in-person classroom setting.

Breakout EDU (www.breakoutedu.com) is an independent company that has popularized the use of escape room concepts in education by developing an open source platform for portable "escape boxes", which are self-contained games based upon escape room concepts designed to be taken into the classroom. Instead of trying to get out of a locked room, the players are trying to get into a locked box. The Breakout EDU platform specifies types of locks and other basic hardware that educators can purchase. Educators can print information from the website or create a game that can be shared with others. A developed escape box can contain props, instructions, and puzzles. Students encounter various types of locked access as they work their way through fictional scenarios. The educator who designs the escape box scenario is the one who incorporates these details into the basic locked access escape box. The Breakout EDU website contains hundreds of games that instructors have created for the platform and uploaded for other educators to use.

Using this Breakout EDU inspired method, an escape box was created for a third-year undergraduate pathophysiology course. The study of pathophysiology is well suited for the use of escape boxes. It is inherently problem-based as it requires learners to integrate their foundational knowledge from prerequisite courses, such as anatomy and physiology, to develop logical potential diagnoses and ideally an accurate final diagnosis. A standard teaching method to assist with the study of pathophysiology and this integration of knowledge is the use of case studies in the form of problem-based learning (PBL) and team-based learning (TBL) (McInerney and Fink 2003, Rendas *et al.* 2006, Vogeltanz-Holm *et al.* 2014). Case studies provide students with initial and sometimes intentionally incomplete information about a patient's signs and symptoms, and students are required to actively inquire and investigate to gain information to develop their potential and final diagnoses. Using escape boxes is a natural progression to further PBL and TBL in the use of case studies in pathophysiology and medical education.

In this article, a pathophysiology case study escape box challenge developed for a small (20 students) third-year undergraduate course is fully described. To provide context to the depth of learning objectives for this activity, students in this course are in a combined Bachelor or Arts and Science program in Public Health. They have taken pre-requisite courses including human anatomy and physiology, infection and immunity, cell and molecular biology, and genetics. These students are positioned to apply to post-graduate clinical education. This article will outline the components, props and delivery of a pathophysiology escape box that was designed for a sepsis/septicemia case study. A debriefing of the escape box at the completion of the challenge is an important part of the learning process and is reviewed. In the Discussion section of this article considerations regarding

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the escape box narrative, recommendations for escape box development, and potential challenges to accommodate larger class sizes, are outlined with the goal of assisting other educators, particularly in pathophysiology or medical education, with escape box development.

Escape Box Components and Parts

The educator/designer of an escape box challenge determines what component parts of the box are required depending on the case study and fictional narrative. Normally, the majority of component parts can be reused in the development of different escape box challenges allowing for extended use of the supplies purchased. While Breakout EDU is a specific platform for teachers to share games, the concepts behind the escape box can be used by anyone to create a live-action classroom game. However, generally it includes a box that can be locked with any variety of locks; a hasp typically used for electrical lockout boxes can hold multiple locks (Figure 1). Locks can be number combinations, lettered word combinations, keyed, or directional. All types of locks can be used in a challenge or the lock type can be limited to only a few types. The role of the lock in the escape box is to provide feedback to the learners; if the learners are correct, the lock will open, if they are wrong, they will know immediately that they need to try again. This immediate physical feedback is one of the powerful aspects of an escape box that makes them engaging for a classroom setting.

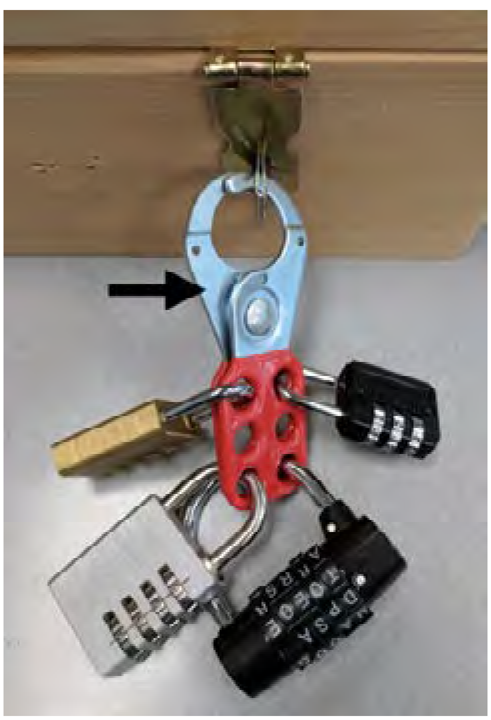

Figure 1. A hasp, (indicated with a black arrow), holding a variety of locks on an escape box.

Escape box kits can be purchased from Breakout EDU or the educator/designer can improvise and build or purchase boxes to suit (Figure 2). For the pathophysiology escape box, the majority of the components were purchased at local hardware, office and medical supply stores. With a class size of 20 students, four identical escape boxes were developed for this challenge. The components of one pathophysiology escape box are listed below:

1. Toolbox (46 x 26 x 26 cm); designed to accept a separately purchased lock
2. 5-letter word combination lock
3. Clipboard with paper
4. Lockable zippered vinyl envelope
5. 3-number combination travel lock
6. Small box (16 x 9 x 11 cm) with lockable latch (key required)
7. One pair of nitrile gloves
8. One urine sample container containing approximately 30 mL of apple cider vinegar
9. Medium lockable box (22 x 15 x 10 cm); designed to accept separately purchased locks
10. Two 4-letter combination locks
11. Large Plastic envelope containing 5 sheets of paper
12. Small zippered purse
13. A variety of items that could be found in a purse: cell phone, gum, condom, lip balm, coffee card, loose change, matches/lighter, but must include a syringe (with needle removed for safety) and elastic headband or small tourniquet

Figure 2. A single lock escape box used in the pathophysiology case study.

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Scenario Overview
The narrative of the pathophysiology escape box has students work in teams as Emergency Room resident physicians. As they work their way through the narrative and scenarios, the students encounter props including triage information, lab results, patient samples, and the personal affects of the patient to enhance the experience and engage with the case study on a physical level. They read scenarios at each stage of the escape box to gain information they can use to solve problems related to the case study or to assist them with the integration of their knowledge. The goal for students is to work as a team to solve problems and provide an accurate tentative diagnosis and treatment plan for the fictional patient. If this goal is achieved, there are a few remaining challenges for them to consider regarding the treatment plan and care of their patient.

The Escape Box Challenge
Escape boxes are rolled into the classroom on a gurney, and the instructor enters in character as an emergency room physician wearing scrubs. Students are welcomed and informed that they have one hour to "Escape the Morbidity and Mortality (M and M) Meeting." It is explained that in a hospital when a physician loses a patient, physicians are required to attend an M and M meeting to discuss individual and systemic issues that may have contributed to the loss of the patient. The goal of an M and M meeting is to try to minimize future preventable patient losses. To be successful at the escape box challenge and "Escape the Morbidity and Mortality Meeting" students are informed that in one hour they must accurately assess and treat their fictional patient, and follow the scenarios and challenges in order to do so.

The first scenario is read to them:

> *You are an Emergency Physician Resident at Wilfrid Laurier Hospital in Brantford. It is Saturday night. It feels as though your shift just began, but you have already evaluated 3 patients with influenza (it is the season), one patient experiencing a severe asthma attack, one suspected myocardial infarction (they are currently getting a ECG), a likely concussion, a ring avulsion injury, and a parade of hematomas and lacerations.*
>
> *There has been a brief lull in triage and your Emergency Resident Supervisor, Dr. Monaghan, has suggested you take a break because you have a long shift still ahead. In the break room you grab a coffee and find a few colleagues working on a crossword puzzle. While you and your colleagues do not typically do crossword puzzles, this crossword is called "Considerations in Emergency Triage and Health History". What the heck... for a laugh, you and your colleagues know this will be a breeze for you and work together on solving the puzzle.*
>
> *There are no more than 5 of you in the break room at a time... please work in groups of 5 or fewer.*

Students are each given a sheet of paper with a crossword. The purpose of the scenario and crossword puzzle (Appendix A) is to initiate students to the scenario, have them establish their team members, and begin working as a team. While this short introduction is primarily to initiate teams and set up the narrative, fundamental terminology is reviewed and students are intentionally passively primed to concepts that they may consider during the escape box challenge.
Instructions on the page with the crossword are as follows:

> *"You and your colleagues in the break room work on the crossword together (no more than 5 to a group). When you are finished, you return to work, but your supervisor questions that you have taken a break – you have a long shift ahead. Once one person in your group shows Dr. Monaghan (your residency supervisor) the completed crossword. It will be viewed as evidence of your break. You will then be given access to your next patient file.*

<u>*Crossword: Across*</u>

1. *Oral 36.8°C, Internal 37°C, and fluctuates*
6. *Think about it: A giraffe requires this to be 3 times greater than in humans*
7. *'Lub-Dub': tachycardia, bradycardia*
8. *calor, dolor, rubor, tumor, and function laesa*
9. *This occurs at the cellular level to produce ATP, or at the systemic level to ventilate*
12. *How many voyages around the sun?*
13. *Has this happened before?*
14. *Undesirable reactions produced by a normal immune system*

<u>*Crossword: Down*</u>

2. *Marijuana, cocaine, MDMA, alcohol, tobacco*
3. *A bag or container's past*
4. *Invasion of body tissues by an organism, their disease causing agents and the reaction of the host*
5. *Anti-depressants, codeine, Ventolin, Tylenol*
10. *'Under the knife'?*
11. *M, F, or U/X*

As a member of each group provides evidence of their completed crossword puzzle, the instructor provides each group with a copy of the following scenario. Additionally, the instructor on their completed crossword circles the word "BLOOD" in "BLOOD PRESSURE". The team member/student is told that the circled word is their Triage Password, and to read the scenario on the page provided and follow the instructions.

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<u>*SCENARIO:*</u>

<u>*Given to each team after they prove they have taken a break (by showing their completed crossword)*</u>

While you were on break, a 25-year-old woman named Caitlin Fraser is brought into ER triage by several of her friends. They said they were out partying until Caitlin was complaining too much about feeling ill. Her friends thought she looked flushed but they were drinking, it was hot in the bar, and they dragged her onto the dance floor at least a few times. It was completely out of character for Caitlin not be interested in going out on a Saturday night, but she said she hadn't been feeling well for several days. They decided to Uber home, but changed their minds and made a pit stop at the hospital's Emergency Department to drop Caitlin off.

The friends left once Caitlin was triaged. You can now access her Triage Information by entering in the Triage Password you were given by your Residency Supervisor.

(Use the Triage Password to open the lock on the box.)

***Please note: All characters in this active learning experience are fictional*

Students use their Triage Password (BLOOD) to open the 5-letter word lock on their escape box and gain access to its contents (Figure 3). Once inside the box students can see:

1. *One clipboard containing "Confidential" Triage Information of a fictional patient*
2. *One small locked black box*
3. *One zippered and travel padlocked envelope labeled "Confidential Lab Results"*
4. *One double-padlocked case with the letter "S" on its lid*
5. *One large plastic envelope labeled "Do not open until instructed to."*

The clipboard containing "Confidential Triage Information" of a fictional patient is the only readily available information. All other contents are locked or labeled not to open until instructed to. The triage information page is designed as a prop to look official on the clipboard. For effect, the university logo was modified to say "hospital" instead of "university" (see Appendix B). On the same page and below the triage information, the scenario is further described:

Figure 3. The pathophysiology escape box contents. Numbering has been added to the image to identify components. Component 1. Confidential Triage Information on a clipboard (see Appendices B and C); Component 2. Small box with lockable latch (requires key), Component 3. Zippered and travel padlocked envelope labeled "Confidential Lab Results", Component 4: One double-padlocked case (with the letter "S" on its lid); Component 5: One large plastic envelope labeled "Do Not Open Until Instructed To".

<u>*SCENARIO:*</u>

> *You do not know what is making Caitlin feel unwell, but recognize she is exhibiting signs and symptoms that could indicate a minor illness that would resolve on its own, or various serious conditions that would require medical intervention.*
>
> *You request that Caitlin provide a urine sample. She says that even though the last time she urinated was about 4 hours ago, she does not have anything to void.*
>
> *You explain to Caitlin that you need to do some blood test in order to gain a better understanding of what might be going on. She agrees and allows for a blood sample to be taken. It is difficult to find a vein, and you notice that she had some unusual venipuncture sites. You inquire and she mentioned that she was not feeling well earlier in the week and her family physician ordered blood work as well. The nurse had a hard time finding a vein so she was "poked" several times before the nurse was successful at getting the sample.*
>
> *You order a CBC (Complete Blood Count), Electrolyte tests, Lactic Acid Test, and Blood Culture.*

At the bottom of the triage page after the scenario, there are instructions to turn the page over. On the reverse side of the page, instructions encourage students to use their internet access to research information on standard ranges and averages of vital signs if they do not recall them from their physiology pre-requisite course. Access to information using technology is a common practice in medicine and is realistic and appropriate for this learning activity. An empty table is provided for students to enter standard ranges to compare

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with the patient's triage information (see Appendix B and Appendix C). What they should notice from this comparison is that the patient's vitals show an elevated temperature, heart rate, and possibly respiratory rate, and a low blood pressure. They may also question the moderate murmur noted at the lower left sternal border (LLSB), but there is no way at this time to determine if the murmur is important in the case, or an artifact. The patient's triage values are designed to be not too extreme that the pathology in the case study is immediately revealed or that the patient is so ill that she dies before students have a chance to think about what is causing her distress. At this point conditions that could cause these altered vitals are extensive and range in severity potentially causing outcomes from discomfort to death.

Further information is provided below the chart students are given to compare standard ranges with the patient's triage vital signs. This information is intended to guide and assist the students at their knowledge level to take the information they are familiar with, such as anaerobic glycolysis, and apply that knowledge to testing they may not have previously been aware existed. The information provided was as follows:

> *Along with the CBC and blood culture, you ordered a Lactic Acid Test. Review the role of glycolysis and lactic acid in the anaerobic production of ATP. Why would someone have higher lactic acid levels?*
>
> *To obtain the access code for Confidential Lab Results in the zippered pouch, correctly fill in the blanks with numbers. In glycolysis, 1 glucose molecule produces a TOTAL of ___ ATP. To produce this ATP it actually uses ___ ATP, resulting in a NET of ___ ATP.*
>
> *** The code can be entered into the lock by looking at the SIDE of the lock where there are number windows to arrange your code.*

The remaining exercises on the page have students reflect on glycolysis and the production of lactic acid in anaerobic conditions. This reflection is intended to inspire students to consider the causes of lactic acid production and anaerobic conditions before they receive more information. When students fill in the blanks on the activity regarding glycolysis, it provides them with the number "422" which is then used to obtain access to the zippered and locked pouch in the escape box.

Unlocking the envelope, students find a file folder prop (Figure 4), containing the Complete Blood Count (CBC) results for the patient (see Appendix D) and an additional piece of paper with the following scenario:

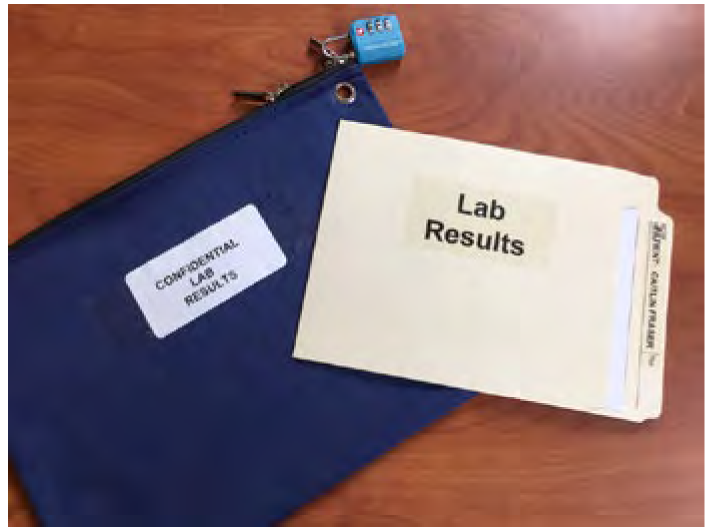

Figure 4. Within the "Confidential Lab Results" zippered and padlocked envelope, is a file folder prop containing the patient's CBC lab results, and a piece of paper with more of the narrative (See Appendix D for lab results).

Please find the Lab Report Enclosed with this Paper

SCENARIO:

> *Caitlin determines she is able to at least try to provide a urine specimen and heads off to the washroom with her urine sample collection pack. Before she returns you receive her blood work results.*
>
> ***Review Caitlin's CBC Lab Results if you have not already.***
>
> *Her CBC indicates leukocytosis, elevated platelets, and elevated lactic acid levels. There are a few other things you notice with her blood work. What are they?*
>
> *Caitlin returns from the washroom and indicates that she is feeling much worse. In fact, she said she almost collapsed in the washroom. Caitlin reports feeling cold, is shivering, but is flushed on her face and extremities. You take her temperature and her fever has increased to 38.7 °C. She also seems out of breath from walking back from the washroom. A new symptom of shortness of breath has presented itself, and her rate of respiration is 24 breaths per minute. Her heart rate has increased to 100 bpm.*
>
> *While you will not have her blood culture back for at least a few days, you recognize this patient is potentially experiencing a very serious medical situation and you consider calling the intensive care unit to discuss her case. First you take your suspicions to your Residency Supervisor.*

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CHALLENGE:

Consider Caitlin's case and her progression. It is true, there are no conclusive answers yet, but you are confident that if your team does not act fast, there will be a dramatic decrease in Caitlin's platelet count, and a potentially fatal progression of her condition. What does the pathogenesis suggest she is experiencing? Talk with your team and write your answer in the space provided.

Have one person from your team approach your Residency Supervisor with your team's diagnosis, and first priority treatment suggestion. Why would you suggest this tentative diagnosis and treatment suggestion?

TENTATIVE DIAGNOSIS:

FIRST TX SUGGESTION:

and WHY?:

***Please note: All characters in this active learning experience are fictional.*

Students are required at this point to integrate their pathophysiology learning objectives from the course, and knowledge from their pre-requisites, in order consider possible diagnoses. They are asked to develop a tentative diagnosis because the information they have been provided, while realistic to how a patient may present, is initially intended to be ambiguous enough to ponder several possibilities. In reality, the information students acquire by the time they need to make a tentative diagnosis and treatment plan is not enough information for a health care provider to be definitive about a diagnosis. Just as in health care, and with the condition of sepsis, evidence-based action must sometimes be taken before suspicions are confirmed through blood culture or other testing.

Students work in their teams to provide the instructor with their tentative diagnosis, first treatment suggestion, and justification for the tentative diagnosis and treatment suggestion. It is expected that students provide "sepsis/ septicemia" as their tentative diagnosis, "broad-spectrum antibiotics/antibiotics" as a first treatment suggestion, and list the points that lead them to this diagnosis and treatment. If student teams develop an incorrect tentative diagnosis, such as respiratory alkalosis, pulmonary embolism or myocardial infarction (which are a few conditions, for example, that could present with an increased respiratory rate) there can be an acknowledgment of where their tentative diagnosis aligns with the signs and symptoms of the patient. Students may highlight other signs and symptoms and provide any number of diagnoses. It is at this point the instructor has an opportunity to see why students were thinking of an incorrect tentative diagnosis, support any correct thinking, and gauge how much the team requires redirection. Once students present their instructor with the correct tentative diagnosis, the instructor, while in character, hands the team a key. There is only one place where a key will work, which is in a small latched black box (Figures 3 and 5).

Using the key, students open the box to find a message, and props (Figure 5). The message states:

Congratulations. You have successfully determined what Caitlin is suffering from. Please observe the contents of this box, and open the white envelope at the bottom of the main escape box, which is labeled, "DO NOT OPEN UNTIL INSTRUCTED TO.

Figure 5. The contents of the small latched box. The box contains a pair of nitrile gloves, and a urine sample container with warmed apple cider vinegar to represent the patient's urine sample. It is intended to be dark to indicate high solute concentration, and fluid conservation mechanisms of the kidney.

Inside the latched box is a pair of nitrile gloves and a urine sample container containing approximately 30 mL of apple cider vinegar to appear as concentrated urine. The non-biological "urine" samples had been warmed in the microwave prior to the escape box challenge to add realism and reflect the temperature from a recent urine sample. In the envelope there are five identical sheets of paper, one for each team member and the following instructions:

Consider the urine sample that was collected. What are important observations regarding this sample? Implications of this sample should make you consider the Renin-Angiotensin-Aldosterone System.

Having determined that your patient needs to be in ICU with broad-spectrum antibiotics to treat what seems to be sepsis/ septicemia you recognize that she will also need to be put on IV-fluids and vasoconstrictors such as norepinephrine and vasopressin. In discussing Caitlin's case with your team members, you realize that not everyone is on the same page;

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perhaps they're just tired from the long shift, but it could be they are not as familiar with the Renin-Angiotensin-Aldosterone System as they should be. You mention this to your Residency Supervisor as part of your risk management training. Your Supervisor tells each one of your team members to create their own RAAS flow chart or mind map to peer mentor each other.

Create a Mind Map or Flow Chart of the Renin-Angiotensin-Aldosterone System in the space provided. What aspects of your mind map/flow chart are influenced by administering IV-fluids and vasoconstrictors to your patient? This should take about 10 minutes. Then turn your paper over.

Students have previous experience with creating mind maps and flow charts in pathophysiology, and specifically in communicating Renin-Angiotensin-Aldosterone System (RAAS). They are at a point in their learning that they should be able to logically work their way through RAAS, describe why there is such a small volume of concentrated urine, and how the treatment of IV-fluid and vasoconstrictors impact RAAS. Before the escape box activity, students are not expected to anticipate the IV-fluid and vasoconstrictor treatment, but once offered the information they should be able to provide justification as to why this treatment would benefit the patient because of their knowledge of RAAS. After the escape box exercise, it is anticipated that students can generate an expanded understanding of sepsis treatment beyond the use of antibiotics, to include IV-fluids and vasoconstrictors.

On the other side of the paper it states:

Please do the activity on the other side of this paper first.

Take 10 minutes to complete the task on the other side of the page before returning to work on this side.

To discover the code for the lock on the Left Side of the Yellow Box (with handle facing you) (Figure 3)*, fill in your correct answer to the question below. Then use the numbers to determine the order of letters in the combination for the lock. On the lock, letters should line up along the red line.*

To discover the code for the lock on the Right Side of the Yellow Box (with handle facing you), consider procoagulant and anticoagulant properties of blood. What condition can occur due to sepsis that essentially has both thrombotic and hemorrhagic properties occurring simultaneously throughout the cardiovascular system?

HINT: If your treatment plan for Caitlin hadn't begun to help, she may have progressed to be bleeding from her venipuncture sites and gums.

Take your answer (3 letters), and add the letter on the top of the yellow box as the fourth letter in the combination lock. On the lock the letters should line up along the red line.

(The letter "S" is on the top of the box.)

The combination locks open with RAAS, and DICS, respectively. With access to the last container in the escape box, students open the box and discover a small empty purse, and collection of items. The items include lip balm, a coffee loyalty card, eye drops, matches, a cell phone, condom, loose change, gum, and a syringe with tourniquet (Figure 6). The needle of the syringe is removed for safety. Inside the lid of the box students read the message:

Figure 6. The contents of the double-padlocked box. Once opening the box, these items are concealed by a small purse. This image represents what a participant can see once the purse has been removed.

Caitlin is now in ICU and you see that her personal belongings were not sent with her. As you pick up her unzipped purse to have sent to ICU, her belongings fall out. While putting everything back in the purse, a nurse informs you of the toxicology results from the urine sample Caitlin provided. Her urine came back positive for opioids. This is not as much of a surprise as it would have been had you not just seen the contents of her purse. Speculate on the possible cause of the sepsis.

Ending the escape box challenge with students becoming accidental voyeurs of the patient's purse has more entertainment value than learning value. However, the props invite discussion during the escape box debriefing regarding potential causes of sepsis.

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Escape Box Debriefing

Once the escape box challenge is complete, an escape box debriefing enhances the educational value of the activity and is an important part of the learning process. It is a way for students to reflect, share, expand and connect more deeply with learning aspect of the escape box. Planned questions guide the debriefing and invite spontaneous discussion. Students can also take away the planned questions for further reflection, review and study.

During the debriefing, the learning objectives of the escape box challenge can be highlighted. For Public Health students in this pathophysiology course this includes their knowledge in health sciences but also learning objectives concerning social determinants of health. Students are informed of the reason sepsis was selected as this escape box challenge. Sepsis affects millions of people annually worldwide and, whether as individuals or as future clinicians, knowledge regarding sepsis can save lives. In Canada, sepsis was an underlying cause or contributing cause of one in 18 deaths in 2011 and contributed to the majority of deaths from infectious disease during the years 2009 to 2011 (Navaneelan *et al.* 2016). In the United States, the Center for Disease Control (CDC) reports that, based on death certificate data during 1999 to 2014, 6 per cent of all deaths were sepsis-related (Epstein *et al.* 2016). It is also relevant to discuss the challenges in reliable data collection on sepsis-related mortality because of several factors including surveillance definitions and the absence of confirmatory tests.

After a brief background on the relevance of using sepsis for the case study, students are invited to reflect and share their thoughts about their initial or retrospective evaluation of the patient's confidential triage information. The following were planned questions regarding the triage component of the activity:

1. Reviewing the triage information, are there any points that stand out more prominently in retrospect?
2. What were your first impressions of the patient? Do you have judgment or biases about the patient's behavior, gender or triage information that may have impacted her health care had this been a real scenario? If so, reflect on what and why that may be the case, and challenge your biases to see another perspective.
3. What about the heart murmur? Could it be related or is it an artifact?
4. What about the venipuncture sites? What are reasons patients may chose not to tell the truth? Do patient's deserve quality health care if they are not truthful with their health care provider? Challenge yourself to see greater societal beliefs and potential consequences for this patient had she been truthful form the start about her intravenous drug use. Would you have taken her illness as seriously? Would you have made different assumptions about the venipuncture sites in triage had she been male? In reflecting on this topic consider other potential biases and try challenging them.

Reviewing the triage information students are encouraged to think of possible conditions or situations that could generate the signs and symptoms the patient presented with in triage, and the pathogenesis of these signs and symptoms in relations to sepsis (Table 1). Specifically what conditions could contribute individually to fever, elevated heart and respiratory rates, and low blood pressure? In relation to sepsis how do these signs and symptoms develop? With students' background knowledge taken into consideration, it is expected that they begin to consider what signs and symptoms heart failure, pneumonia or other infections, sepsis, toxins, or co-occurring conditions could present for a patient. While the "LLSB heart murmur" is part of the patient's triage information, it is not anticipated that students automatically know the short hand for Lower Left Sternal Border, or that endocarditis caused by bacterial infection could cause valve damage, a heart murmur, and spread to cause sepsis. This is a point that can be discussed during debriefing. Students have already studied bacterial toxins and their effects on the immune system in their biology pre-requisites, and have extensively studied the condition of sepsis in their pathophysiology course before they are introduced to the escape box challenge.

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Table 1. Case study presentation with commonly associated conditions and pathogenesis related to sepsis

Presentation	Commonly Associated Conditions	Pathogenesis Related to Sepsis
Fever	infection, neoplasia, conditions that cause inflammation, side effects of medication or recreational drugs	Bacterial toxins such as LPS from gram-negative bacteria act as pyrogens and also stimulate leukocytes to produce endogenous pyrogens. Pyrogens act on the hypothalamus, which is the thermoregulatory center. Fever can also increase heart and respiratory rates.
Elevated Heart Rate	physical exertion, low or high blood pressure, side effects of medications or recreational drugs, stress, heart failure, electrolyte imbalance, hyperthyroidism	Heart rate and contractility increase with an increase in sympathetic tone to the SA node and a decrease in vagal tone. Hypotension inhibits activation of baroreceptors (such as in the carotid sinuses and aortic arch), which increases sympathetic tone, as a compensatory homeostatic mechanism to maintain or normalize blood pressure.
Low Blood Pressure	reduced blood volume, heart failure, sepsis, medication, dehydration, anemia, anaphylaxis	In response to bacterial infection, immune cells release an array of cytokines (including the aforementioned pyrogens). These cytokines are both pro- and anti-inflammatory but some are more prominent in the development of sepsis (Chaudhry *et al.* 2013). Pro-inflammatory cytokines dilate blood vessels, which results in reduced vascular peripheral resistance and a decrease in blood pressure. Insufficient blood flow initially results in lactic acid production as a result of anaerobic glycolysis for the production of ATP. If ATP levels become insufficient, cell death and organ failure occur as a result. Pro-inflammatory cytokines are also linked to the release of tissue factor. Tissue factor promotes micro-thromboses formation in disseminated intravascular coagulation (DIC) and disrupts fibrinolysis (Vervloet *et al.* 1998).
Elevated Respiratory Rate	respiratory alkalosis, diabetic ketoacidosis, heart failure, anxiety, sepsis, pneumonia (infection), cystic fibrosis, pregnancy, heat stroke	Increased respiration occurs in response to stimulation of central and peripheral chemoreceptors that influence medullary and pontine respiratory centers. Fever, low blood pressure and changes in tissue gas pressures are factors related to sepsis that simulate chemoreceptors related to respiration. Increased respiratory rates can also be a result of damage to lung epithelium by the pro-inflammatory cytokines resulting in Acute Respiratory Distress Syndrome (Kim and Hong 2016).

During debriefing of the CBC lab results, students are guided through the results and reminded of learning expectations they should have already accomplished in order to speculate about the patient's CBC values. The following were prepared questions and points to highlight for students:

1. The results indicate values to be outside standard ranges with high white blood cells (WBC), platelets, and lactic acid levels. What are common causes of leukocytosis, thrombocytosis and elevated lactic acid levels?
2. Review the role of inflammation, infection and leukemia in leukocytosis.
3. Review the role of platelets, platelet formation, and coagulation.
4. Review local and systemic conditions that can cause ischemia or hypoxia (such as pulmonary insufficiency, cardiac insufficiency, shock, toxins, embolism, aneurysm, DIC). What initially occurs at the cellular level during ischemia to continue ATP production?
5. What occurs at the cellular if ATP production is insufficient? Review how insufficient ATP influences reactive oxygen species (ROS), membrane integrity, protein folding, intracellular calcium, necrosis and apoptosis.
6. Review the role of lactic acid production in anaerobic glycolysis.

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Considering the third-year undergraduate, non-clinical level of the students their understanding of CBC blood work is expected to be relatively superficial. However, they are familiar with the physiology, cell biology and pathophysiology associated with the elevated values found in the fictional patient's blood work. The activity allows student to see how their knowledge is applied to blood work even though they are not expected to be familiar with lab results. A few specific points need to be made regarding platelet values. These high platelet levels were to indicate an acute-phase response prior to DIC. Platelet levels would be expected to drop dramatically as DIC progresses, as platelets would be recruited in developing micro-thromboses. If the escape box challenge lab results had provided low enough platelet levels to indicate progressed DIC, it would be unlikely that students would be able to save their fictional patient even with the correct diagnosis. Therefore in the design of the escape box, the decision was made to include an acute-phase response despite being beyond the knowledge level of the students. Students are, however, expected to associate platelets with procoagulation and clotting, and the activation of blood coagulation pathways as part of DIC.

The progression of sepsis and discussion of DIC allows for the opportunity to review the condition as a thrombohemorrhagic condition with clotting impairing circulation in the microvasculature, and the paradoxical bleeding that occurs. It is a serious and often fatal complication of sepsis, but discussion can be expanded to include other risk factors for DIC other than sepsis such as blood transfusion reactions, complications in pregnancy, and some leukemias. The platelet levels discussed from the patient's blood work invite discussion regarding the pathogenesis of sepsis, DIC, and how patients will not always present in textbook fashion depending on the progression stage of the condition.

If you want to highlight a few other conditions the blood work reveals, it could be pointed out that the patient's hemoglobin count, while well within standard range, would be considered high for a woman of childbearing age but doesn't register for outside of standard values. It is her high hematocrit level that could falsely elevate her hemoglobin values.

After establishing the correct tentative diagnosis, students are led to review the Renin-Angiotensin-Aldosterone System (RAAS). They have extensively studied RAAS and its implication on blood pressure, blood volume, cardiac contractility, and renal function. From this exercise, it is anticipated that students easily review RAAS, learn that IV-fluid and vasoconstrictors are common treatments for sepsis, and be able to generate a logical justification as to why these are often required treatments for sepsis.

Lastly, debriefing ends with a discussion of the patient's purse contents and the potential causes of sepsis. While this case study was intended to reflect bacterial septicemia potentially caused by contaminated syringes, more common causes of sepsis are pneumonia, urinary tract infections, and abdominal infections such as from appendicitis. Sepsis can be caused by other pathogens and the incidence in sepsis caused by fungal infections is rapidly increasing (Martin 2012).

Discussion

There are several considerations, recommendations and potential challenges to deliberate in the development of a pathophysiology case study into an escape box.

Consideration: The Role of the Narrative

While the physical aspects of the escape boxes are one way that this activity is different from a traditional in-class activity, another key difference is the role of narrative. In escape games, the players are placed in the middle of a story and have a key role that drives that story forward. Well-designed escape games are consistent in their use of narrative, so that every puzzle and item used in the game makes sense in the narrative. Having a consistent narrative conveyed through environmental storytelling helps the players to immerse themselves more fully in the activity (Nicholson 2016).

For a learning environment, the narrative provides something that can get lost in a classroom setting; context. The players can be placed in a role of someone needing to use the information in a setting that simulates something from the real world. The challenges in the game can then either be used before the learners work on a topic area to get them more interested and help them understand why something matters, or after the learners have explored a topic area to reinforce and contextualize learning.

It is through a consistent narrative that the designer brings together a set of tasks, engages the players, and provides this context. Without a narrative, the puzzles will feel shallow to the players, and the novelty of opening a lock instead of getting a mark will wear off quickly. In a well-designed educational escape game, the puzzles and locks should be tools used to create a player experience that helps them to better understand content. The narrative is just as important as the physical components and challenges in creating a good player experience.

In pathophysiology case studies, the narrative can begin to be built around items that occurred naturally in the case study. These could be items that are found in the environment of someone unconscious, the electrocardiogram (ECG) from a stress test, or perhaps the mechanism of injury such as a framing nail from a nail gun. The narrative for the case study first requires creative storytelling to expand from the patient's clinical presentation. In many ways, the development of the narrative is the development of the fictional person associated with the clinical picture, and can play an important additional role in recognizing social factors related to health.

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From the story, what are physical items or props that could be used for students to physically interact with? Humanity, humor and intrigue can be woven into the case study with props to enhance student interest, and in meeting course learning objectives.

Consideration: Timing

This particular escape box challenge was delivered during a three-hour lecture. Within that time the escape box challenge was allocated to the first hour and all groups were able to complete the challenge within the one-hour timeframe. After the challenge, there was flexibility with the amount of time available for the debriefing. The remaining class time was used for debriefing and related relevant and engaged discussion. The debriefing component is essential for learning; as classic learning theorist Dewey presents, education comes from the combination of experience and reflection. Without the reflection, the experience does not lead to long-term learning (Dewey 1916).

With variations on the time apportioned for lectures among universities, the escape box challenge can be designed to take less time to allow for the debriefing to occur immediately after the challenge and within the same lecture, or for the debriefing to be conducted during the subsequent lecture. Another route is to break the game up into chapters so that players engage with a smaller portion of the game, can debrief the experience in class, and then can be encouraged to explore specific topics for the next week's game. It may be of concern to invest several lectures for one activity considering the volume of content normally encompassed in a pathophysiology course. However, escape boxes are active and problem-based learning strategies that bring novelty to the pathophysiology case study. This type of novelty plays an important role in memory formation (Ranganath and Rainer, 2003), the learning objectives of the activity are extensive, and the higher-order integration of knowledge is modeled during debriefing.

Consideration: Flow and Complexity

A key building block theory for game design is the concept of Flow. The theory of Flow is based upon the idea of making a game more challenging as the player gets better. Keeping the player in the state of Flow will keep them engaged and interested in the game. If the game is too complex too quickly, players will be frustrated; if the game does not get more difficult as the players get better, players will be bored (Csikszentmihályi 1990). In the case presented here, the players are first given a low-stakes, narrative-light crossword puzzle. Once they have solved this, they are then ready for the more complex challenges to come. This also allows the team to form so that they are ready to perform as the game continues.

The "Escape the Morbidity and Mortality Meeting" challenge was a relatively linear challenge. Students could consider several conditions but as additional information was provided in scenarios, it was expected that they correctly arrive at the tentative diagnosis. The expectations and amount of flexibility to inquire were appropriate for the students' level of knowledge. If an escape box is being designed for clinicians, a less linear scenario could be designed with potential plot twists, and more significant consequence to error. Options can include dead ends where participants need to back track to reevaluate where they made an error, or fail states where the players can lose the game from choosing incorrectly.

A way to begin development of this type of escape box is to evaluate the learning objectives and identify actions that the clinical learners need to know not to do. From there, in an escape box challenge, if they choose that potentially dangerous option for the patient they enter a dead end scenario as described. Another scenario could be that if the clinical learner selects a dangerous option for a fictional patient (such as selecting the incorrect drug concentration or treatment on a labeled envelope) they may have to meet with their fictional "supervisor" and spend 5 minutes outlining why that option was inappropriate before continuing on the escape box challenge. Creativity is an important key to developing escape boxes and establishing what is to be learned during the activity.

Recommendation: Playtesting and Feedback

Once an escape box is developed and the narrative, props and challenges are in place, it is important to playtest the activity with willing test subjects. On the first playtest there will inevitably be aspects of the challenge that can be flagged for improving clarity, guidance or the narrative. For example, one question raised during the development of this game was: if there is paper in the escape box that has information or activities on both sides of the page, is it important that participants do or read one side first? If so, this needs to be clearly communicated, and numbering the page may not be enough. In the pathophysiology escape box challenge described, this was accomplished by indicating at the bottom of the first page that they should turn the paper over, and at the top of the second page stating, "*Please do the activity on the other side of this paper first*". Another way to deal with this problem would have been to use envelopes with instructions on the front and back that said "Do not open until instructed" (although excited players may open them anyway). A third method is to put different stages of the challenge in different locked containers so that players can't access activities ahead of time.

When playtesting, it is important to ensure that at least some of the playtesters have not had experience with these types of games. Using experienced playtesters can be useful at the beginning of the playtesting process, but as the game is improved, it is important to bring in testers who are more representative of the target players. This is important for exploring the difficulty level of the game; most new designers

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make their games too difficult or include too many challenges on their first pass and have to cut things out to make the game fit within the allotted time.

By observing playtests and incorporating feedback, many or all of the major issues of how the activity will flow for participants will come to light. Once modifications are made from the playtest feedback, it is time to launch the challenge in the classroom setting. Despite the effort and attention to detail that have been invested in the development of the escape box to this point, there may still be little challenges that arise. For example, clear descriptions of where the code for a combination lock lines up are important to include. It can be frustrating for participants if they have the correct answer, figure out the correct combination, but then enter the combination in a way that does not open the lock. To reduce frustration, specific instructions can be included, such as *"On the lock, letters should line up along the red line"* or a lock demonstration can be given before the game is started to ensure everyone knows how to use the locks in the game. Without playtesting, the game will most likely fail in one or many ways when it is launched in the classroom.

Potential Challenge: Class Size
One of the challenges an educator faces is how to deal with large classrooms. The box as it stands only supports about six people around it. One route is to purchase multiple boxes and give each group a complete set of all of the content, props, and boxes, although this can be cost and space prohibitive. Another solution is to have smaller boxes, each for a different challenge, scattered around the room at stations, and the teams work on paper challenges at a table, then when they have a solution, they can try the solution on a lock at a station. They then re-lock the lock for the next group. A third route is to have a ticketing system with a single guess, where teams fill out a ticket with their guess, bring it up to the single box at the front, and stand in a queue to try the lock. The reality is that the locks are simply a way to check an answer and the instructor could look at the answer and tell the team they are right, but that would take away the excitement a learner gets when their skills and knowledge had a small physical impact on the world by opening the lock.

In a larger pathophysiology class, there could be several case studies and teams could be working as departments, such as triage, radiology, and laboratory. This type of escape box challenge could infuse a dynamic of collaboration among teams, urgency, and priority, which are all realistic elements in health care.

Post-Mortem and Conclusion

A post-mortem is an activity commonly practiced in game design where the developers of the game look back at the game after its completion and talk about what worked well, where there were problems, and ways to improve the game experience. In the "Escape the Morbidity and Mortality" challenge, there were several aspects of the game that went well. Many of the challenges aligned with learning objectives or goals regarding the pathology of sepsis and the activity highlighted to students the growth they had experienced as learners. Specifically, students recognized that the complexity of the game would have been beyond their knowledge and ability in previous years, and while they were successful at completing the activity, the challenge was also difficult enough for them to feel accomplished at its completion.

Another success of the escape box was the general excitement that it elicited with a narrative accompanying the case study. During debriefing, pathophysiology was extensively reviewed, but it was clear that students were invested in the fictional character of Caitlin as their patient. Discussion and reflection on the social determinants of health was generated beyond what was typically discussed in the class case study reviews prior to the escape box activity. It appeared that the experience reinvigorated student motivations for taking the course, and for some, their future goals as clinicians. As well, the novelty of interacting with the physical boxes, locks and props created a unique experience that was memorable and stimulated an excitement to work together as their fictional emergency room team. Lastly, the flow of the escape box for participants was straightforward and without incident. This was due to the extensive playtesting that was conducted, which caught many issues that would have otherwise caused confusion. Overall, and anecdotally, the pathophysiology escape box was a success with highlighting student learning, reinvigorating motivation, and creating a memorable experience using novelty.

While there were several successes with the escape box activity, particularly around the support of pathophysiology course learning objectives, from a game design perspective, there are several areas where the narrative and sense of immersion could be improved to potentially enhance the immersion and learning experience. A logistical improvement could be to have teams selected randomly or pre-selected by the instructor. The outcome of students selecting their own teams resulted in students grouping themselves with their peers, which also seemed to align with their academic performance in the course; students doing well in the course grouped with others doing well in the course. All teams were able to accomplish the task, but there were significant differences in academic strength and problem-solving skills among the teams.

Another way this game could be improved is to apply Nicholson's "Ask Why" model (2016) to each step of the narrative to improve the consistency of the world and increase immersion. For example, why does a word taken from five letters of a crossword puzzle open a locked box that contains information about a patient? Who set that lock, and what relationship did they have with the puzzle? If the

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patient was just brought into the hospital during the break, then how did the information about this patient get put into a locked box so quickly? If the "why" question is asked during the time of design, then the design can be changed to create a consistent narrative; it can be difficult when the "why" question is asked later to re-think the underlying structure of the game.

Continuing the "Ask Why", why would the numbers related to three different aspects of ATP be used to lock a pouch? Instead of using an artificial combination of numbers, using something that is a more standard method of combining or reporting numbers from the field would be more natural. Moving on to the next challenge, the players report to the supervisor, who hands them a key. What does that key represent in the game world? What would be locked up that would require a key? In this case, the container could represent the lab, and the players are opening the lab to get at the samples or finding the locked storage in the lab.

When there is a chance to add an additional physical space to the experience, it can help with immersion. In this case, the small box could be placed in another marked area of the classroom, with one envelope per team labeled "Take one envelope and relock the box", so the players could be directed to go into the "lab" and search for the locked storage, with instructions to lock it up once done. This concept of getting players more physically engaged with the game by changing the space is based in environmental storytelling, where elements from the environment convey the narrative.

The next step of the game has the players use diagnostic codes to unlock a box and get Caitlin's effects. Again, applying "Ask Why" concept here leaves a narrative gap to be filled. Why is it that knowing that DIC is a serious complication of sepsis allows access to the personal effects of Caitlin? One way to develop this would be to have Caitlin's purse in another part of the classroom, and have the players get instructions in the box they unlock with the diagnosis that progresses the narrative, telling the players they have successfully diagnosed Caitlin's condition, that she has been moved to ICU, and that the players should go to storage and get Caitlin's belongings. Once they get a purse (which will need to be replaced by the instructor after each team), there will be a card attached to it that moves the story along. This also would be an opportunity to use a video instead of a physical purse, showing hands grabbing and dropping the purse, having items spill out for the players to see, and then the players are given the continuation of the challenges.

Cooperative live-action games bring players together in a physical space, which increases engagement and opportunities to learn from peers. Physical simulations have been a cornerstone in the health training fields, but these can be cost-prohibitive to set up. Escape boxes allow for a lower-cost classroom activity that can use simulation and game design concepts to bring groups of students together and create an intense exploration or review of course content. Creating an escape game is challenging, and as the reader can see is never complete as there are always ways to improve the game. If the game is used every semester, then a second in-class activity can be to ask the students who played the game to then help redevelop the game for the next year; not only can this reinforce the learning, but will serve to give the instructor a chance to learn from their students.

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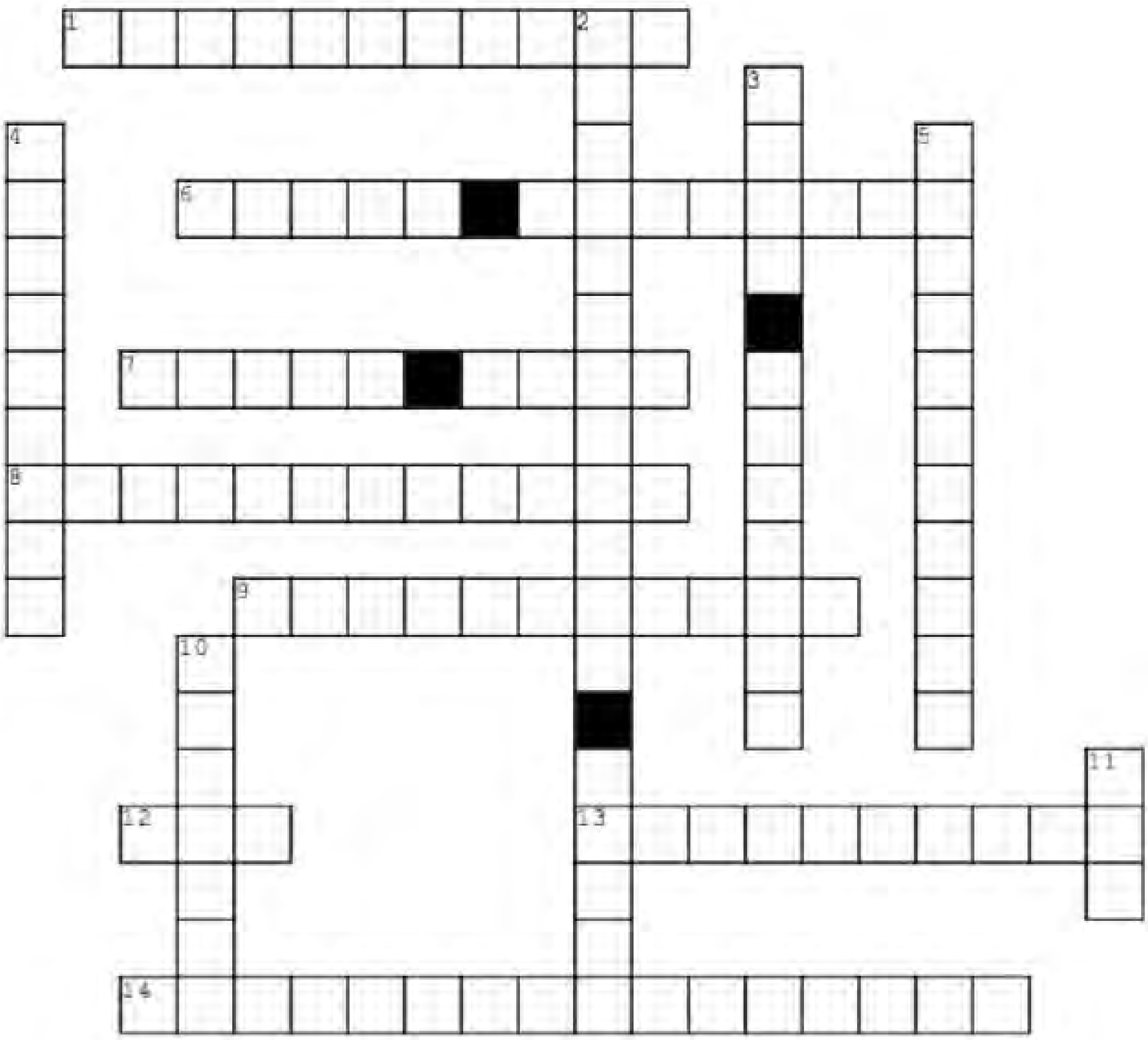
Appendix A. Crossword puzzle used in the initial escape box challenge, generated with Crossword Puzzle Generator at TheTeachersCorner.net.



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Appendix B. Confidential Triage Information found on the clipboard inside the escape box.

CONFIDENTIAL
WILFRID LAURIER HOSPITAL PATIENT TRIAGE INFORMATION

PATIENT NAME: CAITLIN FRASER

D.O.B: AUGUST 1, 1991
AGE: 25
SEX: Female

COMPLAINT: Feeling unwell, feeling hot/fevered, weak, tired. Flushed on face and extremities

TRIAGE HR: 82 BPM; moderate murmur noted at the LLSB, patient unaware of murmur history
TRIAGE TEMP: 38 °C
TRIAGE BP: 100/63 mmHg
TRIAGE RR: 18/min
TRIAGE SaO2: 96%

MEDICATIONS: none, occasionally takes MV

NOTES:
Has been feeling unwell over the past week, but progressively felt worse this evening. She has consumed 3 alcoholic drinks this evening.

Appendix C. Students are encouraged to compare and reflect on the patient's triage values and standard ranges and averages.

CONFIDENTIAL
WILFRID LAURIER HOSPITAL PATIENT TRIAGE INFORMATION

What is the normal standard range, and average for oral temperature, heart rate, blood pressure and respiration? Using Caitlin's Emergency Triage information, evaluate if any of Caitlin's signs appear to be of concern. Do age or sex play a role in these norms? Use your internet access to determine these norms if you do not know.

	Standard Range & Average	Caitlin's Triage Values
Oral Temperature		
Heart Rate		
Blood pressure		
Respiratory Rate		

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Appendix D. The lab results are expected encourage students to think about why there may be elevated WBCs, platelets and lactic acid values in the patient's blood work.

CONFIDENTIAL

WILFRID LAURIER HOSPITAL CBC LAB RESULTS

CBC for Patient: Caitlin Fraser / 25YRS / F

Component Results:

Component	Your Value	Standard Range	Units	Notes
WBC Count	**13.8****	**4.0 – 10.5**	**x10E3/μL**	**H****
RBC Count	5.2	4.10 – 5.60	x10E6/μL	
Hemoglobin	141	125 – 170	g/L	
Hematocrit	46	36.0 – 50.0	%	*
MCV	84	80 – 98	%	
MCH	1.8	1.7 – 1.9	fmol/cell	
MCHC	21.1	19.0 – 22.0	mmol/L	
RDW	44.4	40.0 – 55.0	fL	
Platelets (PLT)	**552****	**140.0 – 415.0**	**x10E3/μL**	**H****
Other:				
Lactic Acid	**2.0****	**0.9 – 1.8**	**mmol/L**	**H****

*** Nearing standard range limits**
**** Outside of standard range limits (H = High, L = Low)**

Appendix E. The answer "Increase Blood Pressure" is added to the spaces. The numbers correspond to letters and the order of the letters for the lock combination. The code is "RAAS".

What is the PRIMARY role of the Renin-Angiotensin-Aldosterone System?

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

2&3 1 4