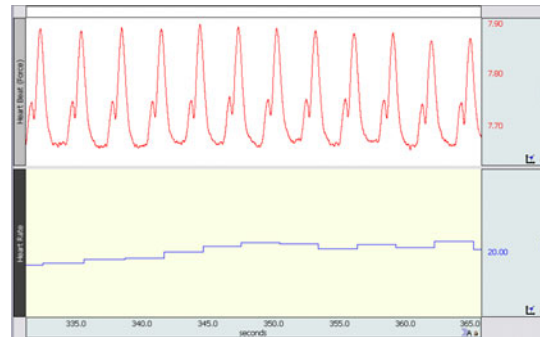
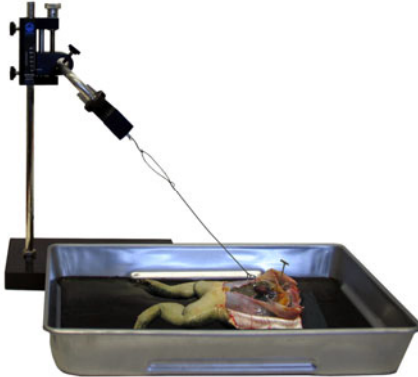


BSL PRO Lesson A04: Effects of Drugs on the Frog Heart

Developed in conjunction with Department of Biology, University of Northern Iowa, Cedar Falls



This *PRO* Lesson explains how to prepare the frog heart and describes the hardware and software setup necessary to record contractile responses and cardiac rate of the frog heart.

Objectives:

1. To observe and record atrial and ventricular behavior (systole and diastole) in the frog heart.
2. To observe and record the effect of increasing and decreasing the temperature of cardiac muscle on cardiac rate and contractility.
3. To observe and record the effect of various drugs on the heart, and explain their mechanisms of action.
4. Optional: To observe the property of myogenicity in the excised frog heart.

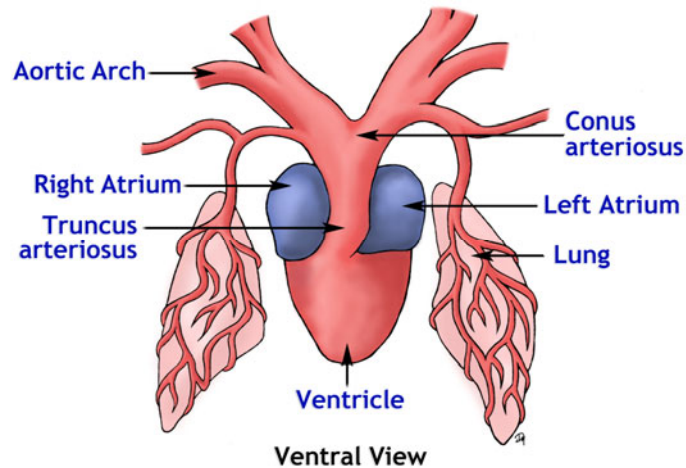
Equipment:

- Biopac Student Lab System:
 - MP36 or MP35 hardware
 - BSL 4.0.1 or greater software
- Force Transducer (SS12LA includes S-hooks)
- Ring stand
- Tension adjuster (HDW100A or equivalent)
- 10 gram weight for calibration (must attach to S-hook)
- Thread (non-stretch nylon or equivalent)
- Live frog
- BSL *PRO* template file: “a04.gtl”
- Drug preparations: (all drugs to be made in Ringer's solution as a solvent); calcium chloride (10 mM); verapamil (10 μ M), digitalis (10 μ M); acetylcholine (5 μ M), atropine (50 μ M); nicotine (10 mM); potassium chloride (30 mM); epinephrine (adrenalin chloride) (5 μ M); propranolol (50 μ M), caffeine (saturated)
- Amphibian Ringer's solution: dissolve in dH₂O: 113 mM (6.604 g/L) **NaCl**, 3.0 mM (0.224 g/L) **KCl**, 2.7 mM (0.397 g/L) **CaCl₂**, 2.5 mM (0.210 g/L) **NaHCO₃**, pH 7.2-7.4. Stable for months at room temperature. Make up three bottles; one at room temperature, one warmed to approx. 37° C / 99° F, and one refrigerated to approx. 5° C / 41° F
- Goggles
- 12 inch Ruler
- Examination/surgical gloves
- Dissection Pan
- Disposable syringes (1 ml tuberculin)
- Dissection Kit: Scalpel, Forceps, Scissors, Dissection Pins, Tape
- Glass probes (can create your own)
- Acrylic Board (for dissection)
- Small hook for connecting thread to the heart (can create your own using 20-22 Ga solid conductor, enamel coated copper wire)
- Small fishing line swivel (optional)

Background:

Although the heart, like skeletal muscle, is striated, it differs from skeletal muscles in several respects. The heartbeat is **automatic**; unlike skeletal muscles, the heart does not have to be stimulated by nerves to contract. This is because action potentials begin spontaneously in the **pacemaker region** (called the SA node) in the right atrium and spread through the ventricles in an automatic, rhythmic cycle.

As can be seen in the exposed frog heart, this causes the atria to contract before the ventricles. Unlike mammals, however, frogs only have one ventricle (Figure 1).



Ventral View
Figure 1

The pacemaker is **myogenic**. A special group of myocytes in the atrium have an unstable membrane potential that depolarizes and repolarizes regularly. When depolarized to threshold, action potentials are produced and conducted by special modified **myocytes** that work like neurons. The electrical signal passes through **intercalated disks** (gap junctions) to **myocardial cells** with contraction ability. As the signal passes across the contractile cells, it increases cytoplasmic Ca^{++} which promotes contraction. Unlike skeletal myocytes, Ca^{++} passes across the cell membrane to activate actinomyosin and produce a force. Little Ca^{++} is stored in sarcoplasmic reticulum like skeletal myocytes.

Although pacemaker activity is endogenous, the de- and repolarization is controlled by autonomic regulation. The heart can also respond to the hormone adrenalin (.i.e. epinephrine). Most commonly, the pacemaker responds to **sympathetic** and **parasympathetic** modulation. Substances secreted by sympathetic neurons (i.e. norepinephrine/noradrenalin) on to the pacemaker cell will speed up its oscillating frequency. On the other hand, secretions from parasympathetic neurons (i.e. acetylcholine) will slow the pacemaker.

Although the heart generates its own beat, external agents can alter the rate of the heartbeat and in some cases the strength of the heartbeat. Agents that either increase or decrease the heart rate are called **chronotropic agents**. Chemicals that alter contractility strength of cardiac muscle are called **inotropic agents**.

A **drug** is a substance that affects some aspect of physiology when given to the body. Drugs may be identical to substances found in the body, such as minerals, vitamins, and hormones or they may be molecules that are uniquely produced by particular plants or fungi. Many drugs marketed by pharmaceutical companies are natural products that have been slightly modified chemically to alter their biological activity.

The biological effects of endogenous compounds (those normally found in the body) vary with their concentration. A normal blood potassium concentration, for example, is necessary for health, but too high a concentration can be fatal. Similarly, the actions exhibited by many hormones at abnormally high concentrations may not occur when the hormones are at their normal concentrations. It is therefore important to distinguish between the **physiological effects** (normal effects) of these substances and their **pharmacological effects** (those that occur when the substances are administered as drugs). A study of the pharmacology of various substances can, however, reveal much about the normal physiology of the body.

When the frog heart is connected by a thread to a force transducer and recording equipment, contractions of the atria and ventricle produce two successive peaks in the recordings.

The strength of contraction is related to the amplitude of these peaks, and the rate of beat can be determined by the distance between the ventricular peaks. The rate of impulse conduction between the atria and ventricle is related to the distance between the atrial and ventricular peaks in the recording of each cycle. The effects of various drugs on the strength of contraction, rate of contraction, and rate of impulse conduction from the atria to the ventricle can therefore be determined.

Since the recordings of the frog heart contractions are in “seconds” of time, the peak to peak period can be converted mathematically to beat frequency (pulses/second or pulses/minute). First, measure the interventricle period in two successive contractions. This will be in “sec.” Simply divide the period length into one (1/seconds) resulting in pulses/second. Most often, we prefer beats/min; so the pulses/second can be multiplied by 60 sec/min to give pulses/min. (Example: interventricular period is 0.75 seconds, pulses/sec is $1/0.75 = 1.33$, pulses/min is $1.33 \text{ pulses/sec} \times 60 \text{ sec/min} = 80 \text{ BPM}$).

Temperature (Q₁₀) change exerts its effect on heart rate through influence on the nervous system as well as directly affecting cardiac metabolism. The effects of temperature change on the surgically exposed frog heart can be observed by dropping warm or cold frog Ringer’s solution directly onto the heart.

Effects of drugs and their clinical significance:

Epinephrine (EPI) is a hormone secreted by the **adrenal medulla** which, together with norepinephrine released as a neurotransmitter by sympathetic nerves, acts to increase both the strength of contraction of the heart and the cardiac rate. Exogenous epinephrine is a **sympathomimetic** drug, since it mimics the effect of sympathetic nerve stimulation.

Propranolol (PROP), clinically it is known as **Inderal**, and is an adrenergic receptor blocker. Propranolol covers the receptors for epinephrine in the pacemaker. If the heart has been stimulated by a **catecholamine**, the effects are antagonized by the blocker.

Acetylcholine (ACH) is a **parasympathomimetic** drug; that is, it mimics the effect of parasympathetic nerve stimulation. ACH is released as a neurotransmitter from the vagus nerve (Cranial Nerve X,) resulting in a decrease in the cardiac rate.

Atropine (ATRO) has the ability to block the effects of parasympathetic nervous stimulation which is useful in a variety of clinical situations. It is used, for example, in ophthalmology to dilate the eyes (parasympathetic nerves cause constriction of the pupils,) and in surgery to dry the mouth, pharynx, and trachea (Glandular secretions that wet these mucous membranes are stimulated by parasympathetic nerves.) Atropine is an alkaloid drug derived from the nightshade plant (the species name, **belladonna**, is often used as the drug name). It blocks the effects of acetylcholine and inhibits the effects of parasympathetic activity on the heart, smooth muscles, and glands. If the cardiac rate is decreased as a result of vagal stimulation, therefore, the administration of atropine will increase this rate. ATRO is thus sympathomimetic in its action.

Nicotine, outside the heart, promotes the release of ACH from preganglionic neurons in autonomic ganglia, resulting in an alteration of autonomic nerve activity and of the secretion of epinephrine from the adrenal medulla. When nicotine is applied directly to the pacemaker, it works like ACH. Generally, it will decrease heart rate.

Caffeine is a mild central nervous system stimulant that also acts directly on the myocardium to increase both the strength of contraction and the cardiac rate. In general this drug increases the life of cAMP within the cell. Its usefulness as a central nervous system stimulant is limited by the fact that, in high doses, it can promote the formation of **ectopic pacemakers (foci)**, resulting in major arrhythmias.

Potassium Ions (K⁺): Since the resting membrane potential is dependent, in part, on the maintenance of a higher concentration of K⁺ on the inside of the cell than on the outside, an increase in the concentration of extracellular K⁺ results in a **decrease in the resting membrane potential**. This, in turn, produces a decrease in the force of contraction and the conduction rate of the action potentials. Therefore, in **hyperkalemia** (high plasma potassium,) the strength of myocardial contraction is reduced and the cells become more electrically excitable, because their resting potential is closer to the threshold required for generating an action potential.

In extreme hyperkalemia, the conduction rate may be so depressed that ectopic pacemakers appear in the ventricles and fibrillation may develop.

Calcium ions (Ca⁺⁺): In addition to the role of calcium in coupling excitation to contraction, the extracellular Ca⁺⁺/Mg⁺⁺ ratio also affects the permeability of the cell membrane. An increase in the extracellular concentration of calcium (above the normal concentration of 4.5-5.5 mEq/L) affects both the electrical properties and the contractility of muscle.

The heart is thus affected in a number of ways by an increase in extracellular calcium: (1) increased force of contraction, (2) decreased cardiac rate, and (3) the appearance of ectopic pacemakers in the ventricles, producing abnormal rhythms (extrasystoles and idioventricular rhythm).

Calcium Blockers: A variety of drugs known as **calcium blockers** are used to inhibit the effects of calcium on the heart. **Verapamil** is commonly used in cardiac management to prevent irregular beating.

Digitalis is a drug frequently used clinically in cases of congestive heart failure, atrial flutter, and atrial fibrillation. Digitalis is helpful in these cases because (1) it increases the force of contraction; (2) it decreases the cardiac rate, directly by inhibiting the SA node and indirectly by stimulating the vagus nerve, which in turn inhibits the SA node; and (3) it decreases the rate of conduction of the bundle of His, thus increasing the P-R interval.

The effects of digitalis are believed to be due to its inhibition of the Na⁺/K⁺ (ATPase) pump. This inhibition results in an influx of Na⁺ and an efflux of K⁺ and is accompanied by an enhanced uptake of calcium ions. The effects of digitalis and of increased extracellular calcium on the heart are thus very similar.

Instructor Note:

The frog heart can only survive a series of four or five of the listed drugs. You must assign a logical series that can be used within a 2-3 hour period. You can assign a different series for each lab group and then have each group share the data files.

Example drug series:

5. Ringer's, EPI, Ringer's, ACH, ACH plus ATRO.
6. Ringer's, ACH, ACH plus ATRO, Ringer's, EPI, EPI plus PROP.
7. Ringer's, Low K, High K, Ringer's, Caffeine.
8. Ringer's, High Ca⁺⁺, High Ca⁺⁺ plus Verapamil, Ringer's, Digitalis.

Setup and Calibration:

It is assumed that the MP36/35 is connected to the host computer and that the Biopac Student Lab software has been installed and is known to work with the MP unit.

1. Turn **OFF** the MP36/35 unit.
2. Plug the SS12LA Force Transducer into CH 1 as shown in Figure 2.

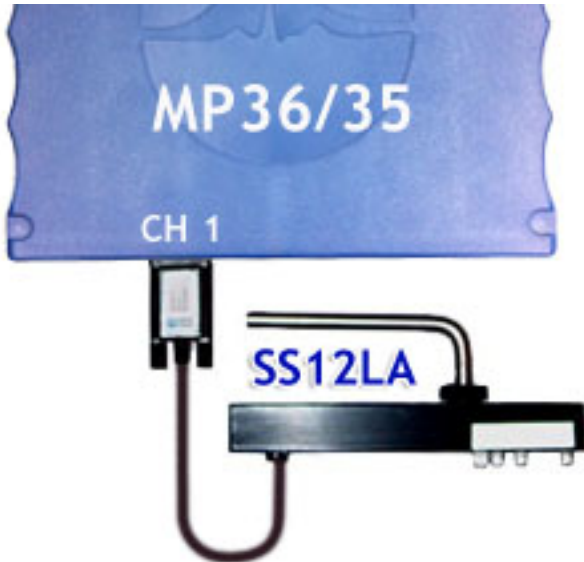


Figure 2



Figure 3

3. Place the tension adjuster (BIOPAC HDW100A or equivalent) on the ring stand (Figure 3), and attach the BIOPAC SS12LA Force transducer such that the hook holes are pointing down. Roughly set so that transducer is level both horizontally and vertically.
4. Set the tension adjuster such that it is approximately $\frac{1}{4}$ the distance from the lowest setting. This will allow the majority of the range to be used for adding tension (raising the adjuster).

Note: Do not firmly tighten any of the thumb-screws at this stage.

5. Place the small "S-hook" into the hole labeled "50 g."
6. Turn **ON** the MP36/35 unit.
7. Launch the BSL *PRO* software and open the template file "a04.gtl" in one of two ways:
 - a) From Startup dialog, click the **PRO Lessons** tab and double-click on the lesson title in the list. If you do not see the lesson title, try the next opening method.
 - b) From Startup dialog, choose the **Create/Record a new experiment** option, click **Open Graph template from disk** and then click OK. Navigate to the file, select it and click **Open**.
8. Enter in a unique name and click OK. A folder with that name will be created and at the end of the lesson the data file will be automatically stored in this folder. Figure 4 shows the position of the lesson buttons.

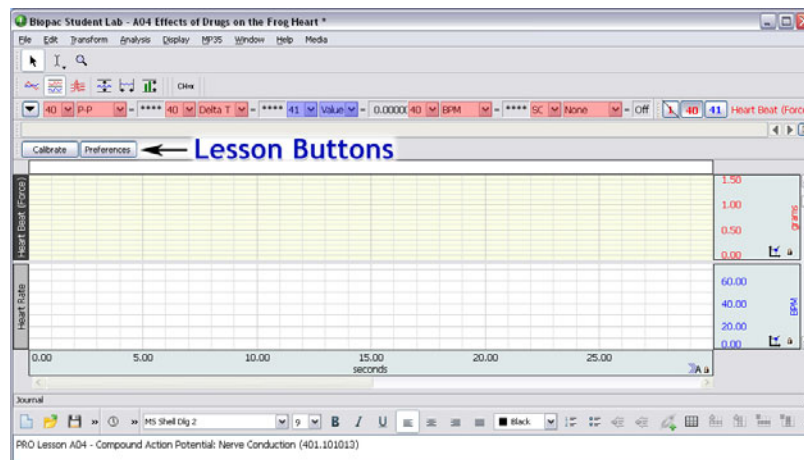


Figure 4

Notes:

- If you do not see the Lesson Buttons upon launching the graph template, go to **“Display > Preferences > Graph”** and change the Display Style from **“Tabbed”** to **“Windowed.”** You will then need to close then re-run the application and open the template.
 - Two calculation channels are displayed; CH 40 – Heart Beat (Force) which runs a 5 Hz Low Pass filter on CH 1 data, and CH 41 – Heart Rate which runs a rate calculation from CH 40 data.
 - If the last calibration was performed using the same transducer, then click **Next** to skip calibration and proceed to the next section.
9. Click **Calibrate** and follow the instructions in the pop-up dialogs. The first calibration is performed with only the S-hook attached to the force transducer (Figure 5). The second calibration is performed with a 10 gram weight attached, but after it has stopped swinging (Figure 6).

Note: Do not touch the bronze weight with exposed fingers, hands or frog Ringer’s solution.

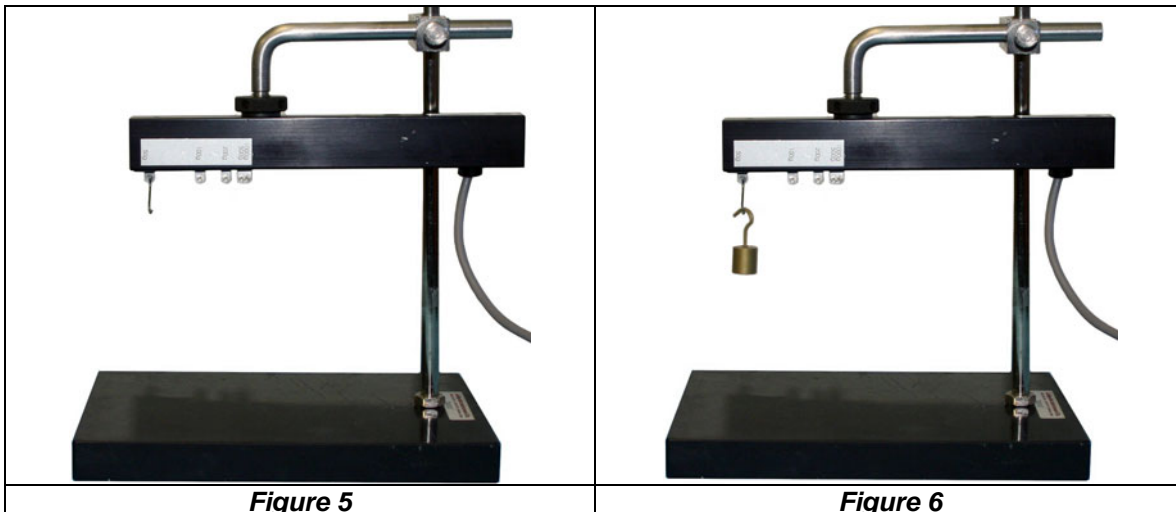


Figure 5

Figure 6

FROG PREP:

Double-pith the frog (if necessary, see [BSL PRO Lesson A01 – Frog Preparation](#) for details). You should apply amphibian Ringer’s solution to the frog in five-minute intervals.

- Carefully expose the frog heart.
 - Cut the skin from the groin to the throat of the frog.
 - Cut through the pectoral girdle to expose the heart in the pericardial sac.

- c. Use dissection pins to hold the body to the dissection tray. Only two pins are needed as shown in Figure 10.



Figure 7



Figure 8

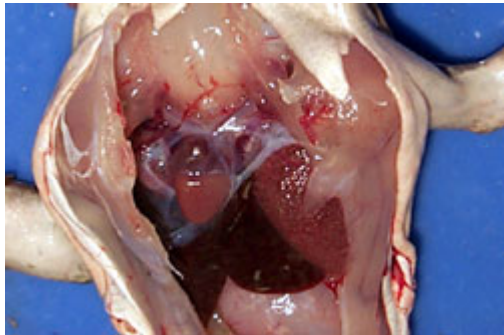


Figure 9



Figure 10

2. Attach a small hook tied with thread to the frog heart (Figure 11).
- If possible, use a hook that has an insulated coating. Making a hook out of 20-22 Ga solid core enamel coated copper wire works well. File the end of the wire to create a sharp point.
 - Tie the line to the hook prior to attaching to the heart.
 - Use a thread that will not stretch under tension (such as non-stretch nylon).
 - Use a knot that will not allow the line to lengthen or come undone under tension (such as the Bowline knot or Square knot (tied twice)).
 - Pierce the heart as close as possible to the bottom tip but with enough surrounding muscle so that the hook will not easily tear out. It may be necessary to use forceps to insert the hook.
 - Keep the frog moist using Ringer's solution while performing the setup procedure.

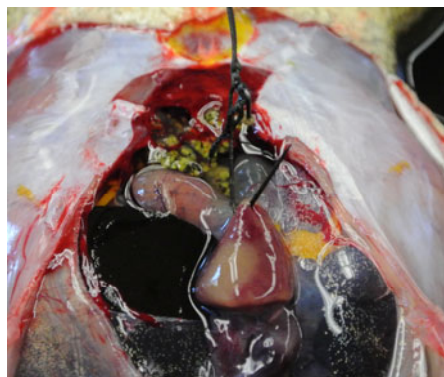


Figure 11

3. Position the force transducer.
 - a. Rotate the Force Transducer such that the thread will pull on the heart at roughly a 45 degree angle as shown in Figure 12.
 - b. The Ring Stand should be able to slide parallel to the pan to allow course changes in line tension (see Figure 13).
 - c. Place the Force Transducer as close as possible to the Ring Stand to minimize movement.
 - d. Position the Force transducer cables such that they cannot be easily pulled or bumped. If necessary, use tape to adhere cables to the tray or ring stand to relieve strain or pull.
 - e. Position the Tension Adjuster such that the Adjustment knob is easily accessible without bumping cables or the tray during adjustment.
 - f. Set up the dissection tray such that it is very stable and will not wobble or rock.

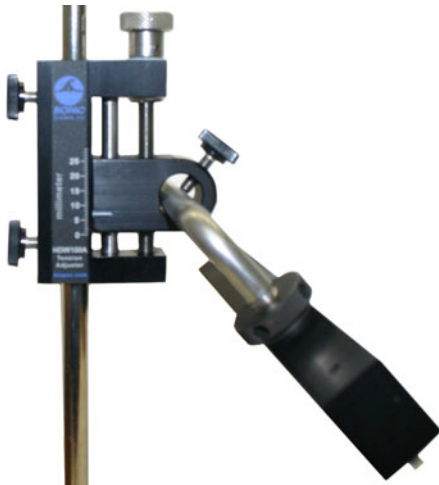


Figure 12

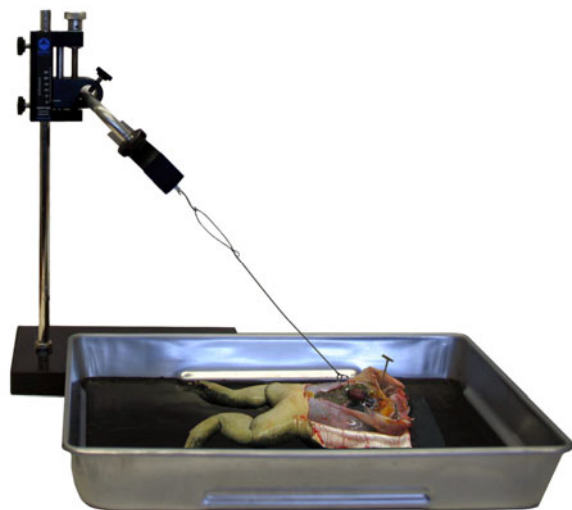


Figure 13

4. Connect the thread to the force transducer.

Measure the required thread length, and then create a large loop in the end of the thread that can easily slip onto the S-hook. Optionally, you can tie the line onto one end of a fishing line swivel and other end will slip onto the S-hook. The swivel will prevent the thread from twisting which can cause recording artifact.

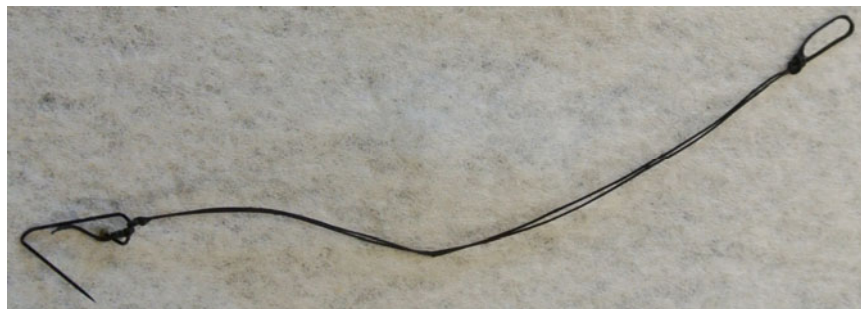


Figure 14

5. Adjust transducer pretension
 - a. Slide the Ring Stand toward the frog and place the thread on the S-hook without pulling on the heart.
 - b. Carefully slide the Ring Stand back until there is almost tension on the line. Do not apply tension!
 - c. Tighten all thumb-screws to secure the Force Transducer and Tension Adjuster.

- d. Use the Tension adjuster Knob to make the line taught — very little tension is required.

DO NOT OVER-TIGHTEN!

- e. Let the setup sit for a minute, then re-check the tension to make sure nothing has slipped or stretched.

Tension Adjust

This mode is used to fine tune the line tension or adjust the setup as necessary to display the frog heart contractions. Data displayed in this mode will not be saved.

1. Rinse the heart with Ringer's solution until the heartbeat is stable.
2. Click **Test**.
3. Examine the data:
 - The Heart Beat (Force) waveform on CH 40 can vary based on frog size and vitality and force transducer position, but it should be possible to record two successive peaks from the atria and ventricle contractions, as shown in the Figure 15 example.
 - Depending on the signal amplitude, you may need to expand the vertical scale in order to see the detail in the heart beat signal (CH 40). If you are not familiar with how to expand the scales (Zoom tool, etc.), see the Appendix.
 - The Heart Rate data on CH 41 will not be valid for the first few cardiac cycles after the start of each recording. After this, the rate should update after each cardiac cycle and there should not be erratic swings (i.e. 50 BPM). Rate data may display artifact from table movement, external pressure on the heart (i.e. breathing on the heart), and from chemicals applied to the heart. To get the best data, keep the experimental area clean, clear and stable. Note that the calculated rate always trails the actual rate by one cardiac cycle.

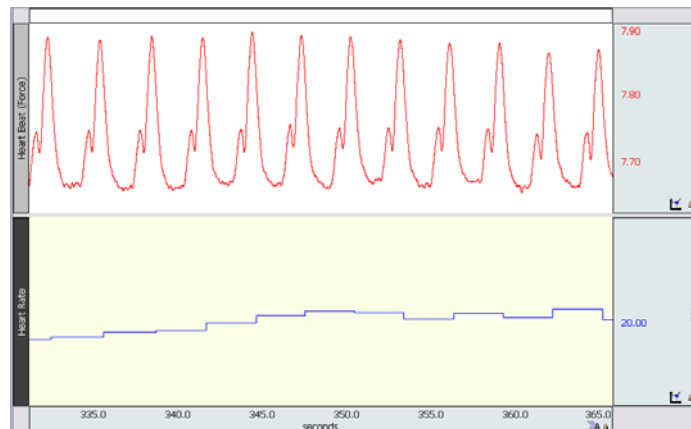


Figure 15

If you cannot see two successive peaks for each heart beat:

- Try slightly adjusting the line tension (less or more) and observe the signal.
- Change the angle of the force transducer.
- Make sure the line is not twisted and correct if necessary.

Note: Adjusting the line tension will change the signal's baseline. You may need to zoom in or out on the data. Choose **Display > Autoscale Waveforms** and/or adjust the vertical scale in order to properly view the data.

4. Click **Stop**.
5. Click **Next** to proceed to the recordings.

Recording Modes

One data file containing several recordings will be saved for this lesson. Each successive recording will be appended onto the previous one. This lesson is broken down into a sequential series of recording modes each of which can contain multiple recordings. The recording mode will be shown in the far left lesson button (Figure 16). For each recording mode after Baseline, upon clicking **Next**, the user must select a title from the dialog as shown in Figure 17. Choose **Other** to enter a custom title. The title will be assigned to the append marker label to help locate data during analysis.

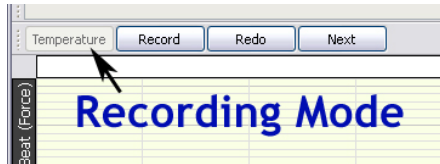


Figure 16

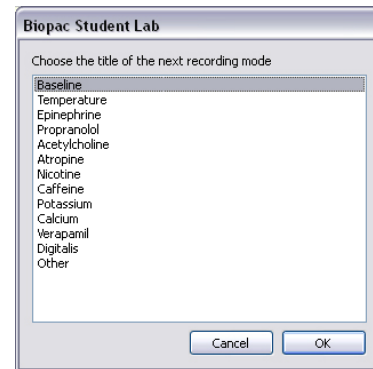


Figure 17

Notes:

- Since the frog heart cannot survive the entire series of listed drugs, you will not be using all of the recording modes. Check with your instructor to determine which series of drugs and recording modes your lab group will use.
- It may be necessary to re-adjust the thread tension if the amplitude on CH 40 (Force) becomes significantly reduced when the heart is in its resting state (prior to application of a drug). If after beginning a recording, you notice a signal problem, carefully adjust the tension then click Stop, Redo, and then Record. Do not adjust the tension in the Propranolol, Atropine or Verapamil recording modes (if used).
- The Heart Rate data (CH 40) may not be able to be calculated reliably. If this is the case, the channel can be hidden during Analysis.
- Always review the recording steps prior to clicking Record.

1. Baseline

This mode is used to record baseline data.

1. Click **Record**.
2. Record for about 10 seconds, and then click **Stop**.
3. Verify that the data is correct. If necessary, adjust the tension, Redo and repeat the recording.
4. Click **Next** to proceed.

2. Temperature

This mode is used to observe the effect of temperature on the frog heart. You should have three bottles of Ringer's solution at your access; one at room temperature, one warmed to approx 37° C / 99° F, and one refrigerated to approx. 5° C / 41° F

1. Click **Record**.
2. Record for a few seconds and then using a dropper; bathe the heart in warmed Ringer's.
3. Look for a change in the CH 40 (Force) amplitude and/or pulse rate which should occur after a few seconds. Continue to record for an additional 10 seconds.

4. Press **F9** to insert an event marker, and then bathe the heart in refrigerated Ringer's.
5. Look for a change in the amplitude and/or pulse rate which should occur after a few seconds. Continue to record for an additional 10 seconds.
6. Click **Stop**.
7. Irrigate the heart with room temperature Ringer's and wait until the heart rate is stable.
8. Click **Next** to proceed.

3. Epinephrine

1. Click **Record**.
2. Wait a few seconds, and then inject 0.05 to 0.10 ml of Epinephrine (EPI) into the vena cava just anterior to the heart.
3. Continue to record for at least 3 minutes, and then click **Stop**.
4. Click **Next** and quickly proceed to the Propranolol recording.

4. Propranolol

Note: Do not adjust the tension in this recording mode.

1. Click **Record**.
2. While the heart rate is accelerated by EPI, inject 0.05-0.10 ml of Propranolol solution in to the vena cava.
3. Continue to record for at least 3 minutes, and then click **Stop**.
4. Click **Next** to proceed.

5. Acetylcholine

1. Thoroughly rinse the heart with Ringer's solution until the beat returns to the normal rate.
2. Click **Record**.
3. Inject 0.05-0.10 ml of Acetylcholine (ACH) into the heart.
4. Continue to record for at least 3 minutes, and then click **Stop**.
5. Click **Next** and quickly proceed to the Atropine recording.

6. Atropine

Note: Do not adjust the tension in this recording mode.

1. Click **Record**.
2. While the heart is still under the influence of ACH, Inject 0.05-0.10 ml of atropine into vena cava.
3. Continue to record for at least 3 minutes, and then click **Stop**.
4. Click **Next** to proceed.

7. Nicotine

1. Thoroughly rinse the heart with Ringer's solution until the beat returns to normal.
2. Click **Record**.
3. Wait a few seconds, and then inject the heart with 0.05-0.10 ml of nicotine solution.
4. Continue to record for at least 3 minutes, and then click **Stop**.
5. Click **Next** to proceed.

8. Caffeine

1. Thoroughly rinse the heart with Ringer's solution until the beat returns to normal.
2. Click **Record**.
6. Wait a few seconds, and then using a dropper, bathe the heart with a saturated solution of caffeine.
7. Continue to record for at least 3 minutes, and then click **Stop**.
8. Click **Next** to proceed.

9. Potassium Chloride

1. Thoroughly rinse the heart with Ringer's solution until the beat returns to normal.
2. Click **Record**.
3. Using a dropper, bathe the heart in a 30 mM solution of potassium chloride (KCl).
4. Continue to record for at least 3 minutes, and then click **Stop**.
5. Click **Next** to proceed.

10. Calcium Chloride

1. Thoroughly rinse the heart with Ringer's solution (1 mM of CaCl_2) until the beat returns to normal.
2. Click **Record**.
3. Using a dropper, bathe the heart in a 10 mM solution of calcium chloride (CaCl_2).
4. Continue to record for at least 3 minutes, and then click **Stop**.
5. Click **Next** and quickly proceed to the Verapamil recording.

11. Verapamil

Note: Do not adjust the tension in this recording mode.

1. Wait for the frog heart to resume a normal beat while being bathed with Ringer's solution (1 mM of CaCl_2).
2. Click **Record**.
3. Wash the heart thoroughly with the Verapamil solution.
4. Continue to record for at least 3 minutes, and then click **Stop**.
5. Click **Next** to proceed.

12. Digitalis

1. Thoroughly rinse the heart with Ringer's solution (1 mM of CaCl_2) until the beat returns to normal.
2. Click **Record**.
3. Using a dropper, bathe the heart in a 2.0% solution of Digitalis.
4. Continue to record for at least 3 minutes, and then click **Stop**.
5. Click **Next** to proceed.

13. Optional

Use this recording mode to perform optional recordings.

Done

Click **Done** to end the lesson and automatically save the data.

From the **Done** dialog, you may choose to analyze the data immediately or copy it to a different location (i.e. thumb drive) for analysis on another computer.

Optional: Property of Myogenicity

Note: This can only be performed after all of the data recordings have been done to satisfaction.

1. Excise the frog heart.

Note that the excised heart continues to generate a beat (Figure 18).



Figure 18

2. Using a scalpel or fine scissors split the heart chambers (Figure 19).

Note that each chamber will generate its own beat, but at different rates.

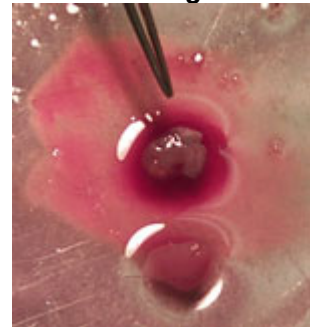


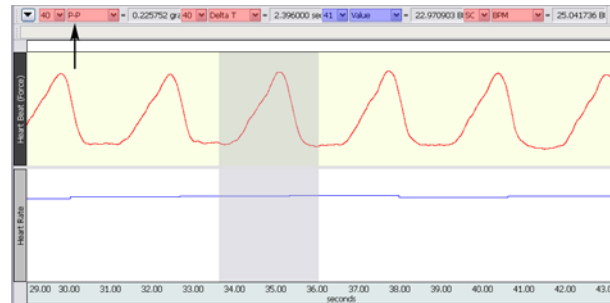
Figure 19

Data Analysis Suggestions:

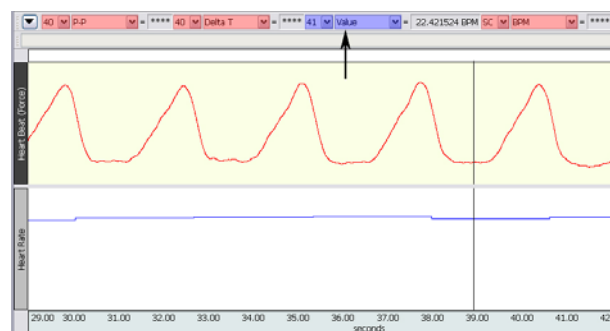
Fill in the following table for conditions that were recorded.

Measurement examples:

To measure the amplitude, select an area that encompasses one cardiac cycle (including baseline) and use the CH 40 peak-to-peak (P-P) measurement (Figure 20).

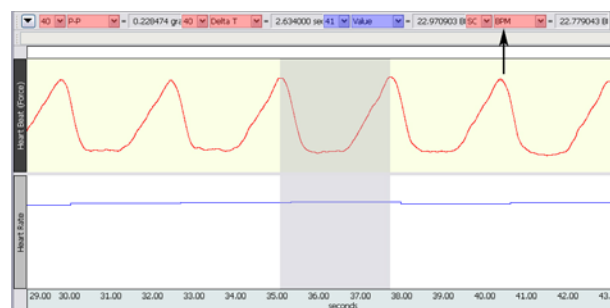
**Figure 20**

To measure the Pulse Rate use the “I-beam” cursor and click on the desired portion of the Heart Rate data and then read the CH 41 **Value** measurement (Figure 21).

**Figure 21**

Alternately you can select an area from one pulse peak to the next pulse peak and use the CH 40 **BPM** measurement (Figure 22).

Note: The CH 41 Value measurement displays BPM for the interval preceding the current interval. This means the BPM measurements shown in Figure 21 and Figure 22 should be nearly identical.

**Figure 22**

Condition	Amplitude (P-P)	Pulse Rate	Time between Atrial and Ventricular Peaks (Delta T)
Baseline			
Warm			
Cold			
Epinephrine			
Propranolol			
Acetylcholine			
Atropine			
Nicotine			
Caffeine			
Potassium Chloride			
Calcium Chloride			
Verapamil			
Digitalis			
Optional			

Questions:

Match the following:

- | | |
|---|-------------------|
| ___ 1. Endogenous substance that makes the beat stronger and faster | (a) digitalis |
| ___ 2. Substance that makes the beat slower and stronger | (b) nicotine |
| ___ 3. Substance is released from parasympathetic nerve endings | (c) caffeine |
| ___ 4. Substance that promotes the activity of the autonomic nervous system | (d) epinephrine |
| | (e) acetylcholine |

5. What are the effects of hyperkalemia on the heart? How are these effects produced?

6. What is a sympathomimetic drug? What are its effects on the heart?



7. What effect did Ca^{++} have on the amplitude of the recording of the heartbeat? Explain why Ca^{++} had this effect.

8. Explain the effect of digitalis on the heart and the clinical uses of this drug.

Appendix 1:


Autoscaling data:

Graph data can be autoscaled vertically and horizontally for enhanced viewing.


- Autoscale vertically by using the  toolbar button or “Display > Autoscale Waveforms” to optimize the vertical display and allow closer examination of the waveform.
- Autoscale horizontally by using the  toolbar button or “Display > Autoscale Horizontal” to display the entire horizontal time scale in a single graph window.

Zooming in and out of data:

Use the Zoom tool to magnify portions of the waveform for a closer look.

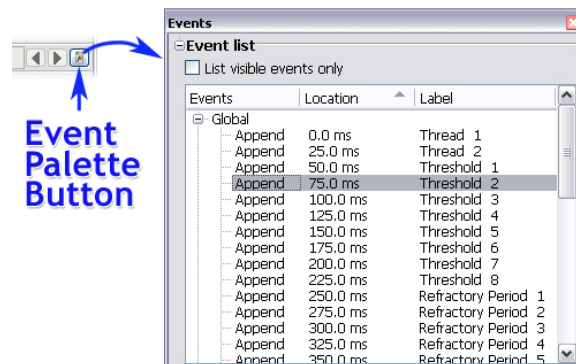
- Zoom in by selecting the  toolbar icon and click/drag over the area of interest.
- To zoom back, use Ctrl – (minus) or “Display > Zoom Back.”

Using the Event Palette to quickly locate Event Markers in the graph:


An easy way to locate event markers in the graph is by using the Event Palette, accessible by clicking the  toolbar icon or via “Display > Show > Event Palette.”

Zoom in on any section of data, highlight an event in the Event list, and the portion of data corresponding to that event will be displayed in the graph. Other features in the Event Palette include summarizing, renaming, removing or editing existing events.

To navigate quickly through consecutive event markers, use the arrows to the left of the Event Palette toolbar icon.



Measurements used in BSL PRO Lesson A04:

Graph data measurements are taken by using the I-beam tool  to select an area of interest. The following basic measurements are used in this experiment:

- P-P (Peak-to-Peak) Shows the difference between the maximum amplitude value and the minimum amplitude value in the selected area.
- Value Shows the data value at the cursor position, or if an area is selected, the data value at the end of the selection.
- Delta-T Shows the horizontal axis time value in the selected area.
- BPM The Beats Per Minute measurement first calculates the difference between the beginning and end of the selected area (second/beat), and divides this value into 60 seconds/minute.

For a full explanation of the features described above, see the BSL PRO Tutorial or BSL PRO Software Guide.