

Chapter 3

Using Computer-Interfaced Physiological Measurement Systems in the Biology Laboratory

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Introduction

These two laboratory exercises are intended for students in general biology students although they could serve as introductory exercises for physiology students as well. Each exercise is designed to be completed in 1.5 hours by a student with little or no background in the subject. The relatively short completion time can be used to advantage in two different ways. One use is to conserve on the number of computer set-ups required by having half the class use the equipment during the first 1.5 hours of lab and the other half using the equipment the second 1.5 hours of lab. A second use of the short completion time would be to have students follow the planned exercise with an exercise of their own design (see Appendix A). Such an exercise can be used in its abbreviated form during a 3-hour lab or in an expanded form as a semester-long project.

Relatively little set up time is required for these exercises once the equipment is purchased and initially installed. Installation of the computers on mobile carts will facilitate set up and will encourage use of this equipment in more than one laboratory and by more than one instructor (Appendix B).

Materials

For **ECG exercise** each group of four students requires:

- Computer with Cardiocomp attachments (Appendix B)
- Flat plate electrodes with rubber straps (4)
- Alcohol swabs per subject (4; one subject per group)
- Hand calculator

For **spirometry exercise** each group of four students requires:

- Computer with Spirocomp attachments (Appendix B)
- Phipps and Bird wet spirometer as modified (Appendix B)
- One-way valve assembly soaking in 75% ethanol solution
- Container of mild soap solution to immerse valve assembly
- One disposable mouthpiece per subject (one subject per group)
- Nose clip also soaking in ethanol solution

Student Outline: Electrical Activity of the Human Heart

The heart is a muscle that must contract in a coordinated fashion to be effective. First, the atria must contract in unison to fill the relaxed ventricles with blood. Then the ventricles contract and pump the blood out to the arteries. Then both chambers relax momentarily filling passively in preparation for the next beat.

The heart has a specialized electrical conduction system to quickly activate first the atria in unison, then the ventricles (see Figure 3.1). The impulse begins spontaneously in the SA node of the right atrium then travels quickly through both atria causing the atria to contract as a unit. Then the impulse is picked up in the AV node and quickly travels down the septum separating the ventricles and activates both ventricles as a unit causing them to contract.

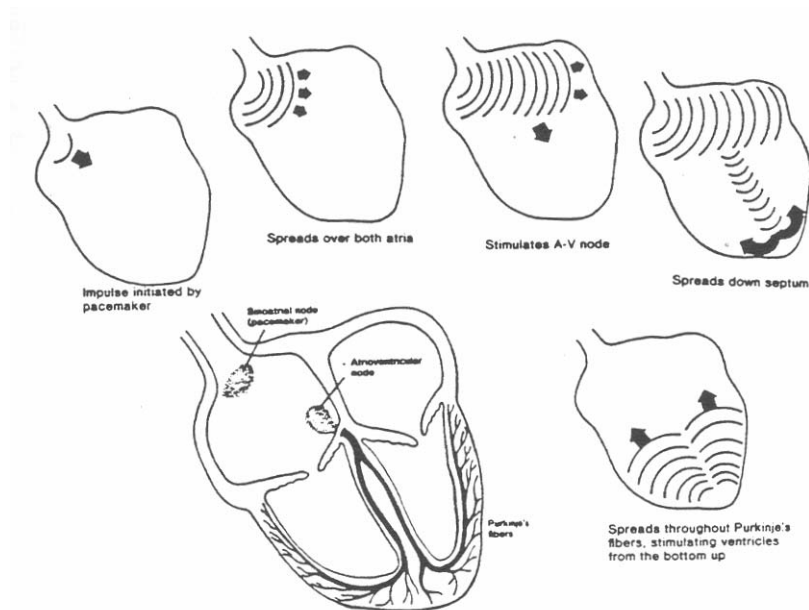


Figure 3.1. The heart's electrical conduction system.

The electrical activity generated by the heart may be detected at the surface of the body and recorded to make a tracing called an electrocardiogram or ECG (see Figure 3.2). Characteristic tracings are made by atria depolarizing (P), ventricles depolarizing (QRS), and ventricles repolarizing (T). Atrial repolarization is hidden within the large QRS segment.

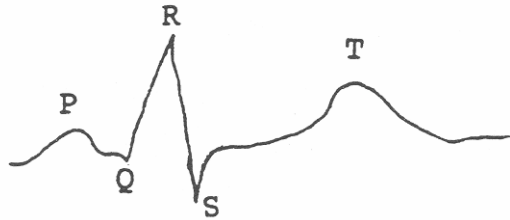


Figure 3.2. The electrocardiogram (ECG).

Exercise 1: The Electrocardiogram

Materials

Alcohol swabs
Flat plate electrodes with rubber straps (4)
Computer with Cardiocomp attachments
Hand calculator

Procedure: Overview

1. Select a subject who is willing and able to run in place for 2 minutes during the course of this exercise.
2. *Scrub* the inside of each arm about 2 inches above the wrist with an alcohol swab. *Place* the alcohol swab under the electrode plate to help improve conductivity and *attach* the plate to the wrist using the rubber straps.
3. Use a similar procedure to *attach* the remaining two electrodes to the inner surface of each leg about 2 inches above the ankle.
4. The subject should lie motionless on the table as his or her lab partners record enough resting heartbeats to obtain a clear tracing of three consecutive beats. This tracing will be stored on computer disk for later analysis.
5. The subject should leave the plate electrodes on but *unsnap* the wires as he or she runs in place for approximately 2 minutes until the heart rate is considerably elevated.
6. Immediately upon stopping, the subject is to get back on the table, *re-snap* the wires onto the posts on the plate electrodes and *record* two more sets of measurements which will also be stored for later analysis. One recording will be taken *immediately post-exercise*. The other recording will be *2 minutes post-exercise*. Again, three clear consecutive tracings will be needed to perform the required analyses.

Procedure: Using the Computer

General Instructions

1. The computer and all components (screen, printer, etc.) are turned on simultaneously by plugging in the surge protector (junction box) and toggling the switch on top of the box to the left (toward the dot). Wait for the computer to “boot” and display the first menu.
2. At this time you should check to see that the printer has paper in it and that it is “on-line” (green light) and ready for use.
3. Place the student data disk in drive A ready for later use. You are now ready to use Cardiocomp.

Note:

- The *up* and *down* arrow keys move the cursor up and down on the menus.
- The *Enter* or return key is used to select the item the cursor is on.
- The *Escape* key is used to back up one step in the operation you are performing. Several “Esc” entries may be needed to return you to the main menu if you are several steps into an operation.

Instructions for Cardiocomp Data Collection

1. Select *<Cardiocomp>* from the first menu by pressing *<Enter>* then *follow screen instructions*:
 - (a) Press any key to begin.
 - (b) The “number lock” must be removed. Press *<Num lock>* at the upper left corner of the numeric key pad. The “number lock” light should now be off.
 - (c) Say *<y>* or “yes” to the next screen question (i.e., printer should say “yes” and the Cardiocomp board is in Hex 310, the standard location).
2. Select *<Experiment Menu>*.
3. Place the cursor over *<Real Time ECG>*. When you push return the ECG will begin recording and will continue until you press *<S>* for “stop” or *<C>* for “clear and restart”. The computer memory can store up to 20 frames before it goes back to overwrite frame 1 but you only need one good frame. Once you see a frame with three clear consecutive “beats”, press *<S>*.

Your subject should have all four electrodes in place as described above. The color coded wires snap onto the small posts on the plate electrodes. The white wire should be connected to the right arm, black wire to left arm, green wire to right leg, and red wire to left leg. The other end of each wire should be plugged into the cardiocomp board using the labels as a guide. *All connections must be secure* or there will be static in the recording.

When your subject is on the table motionless, select *<Real Time ECG>* watch for a screen with at least three consecutive good tracings then press *<S>* to stop the recording.

4. Next push *<Esc>* to back up to the Cardiocomp Experiment menu then *<Esc>* again to back up to the Cardiocomp-7 main menu.
5. Select *<Data File/Disk Commands>*. Then select *<Save Data Now in Memory>*. When asked for a file name, type the subject's name followed by a 1 (e.g., *Bonnie1*) indicating that this is the first or resting trial from this subject. Press *<Enter>* and the file will be saved.
6. *<Esc>* will return you to the main menu. Select *<Experiment Menu>*. Place the cursor over *<Real Time ECG>* but do not hit the *<Enter>* until you are ready to record your second ECG.

7. Detach the electrodes from the metal plates, have the subject run in place for 2 minutes or until the heart rate is well elevated, then reattach the electrodes, have the subject lie motionless on the table and press <Enter> to start the second recording.
8. As soon as a screen appears with three consecutive clear beats press <S> to stop the recording and have one partner begin timing the 2-minute interval until the third recording is due.
9. Meanwhile, a different partner should save recording two following the same procedure as before, that is, press <Esc> twice to return to the main menu, select <Data File/Disk Commands>, then select <Save Data Now in Memory>. <Name> the file after your subject followed by a 2 (e.g., *Bonnie2*), and press <Enter>.
10. The file has been saved, now get ready for the last recording. <Esc> returns you to the main menu. Select the <Experiment Menu>. Place the cursor over <Real Time ECG> but do not press <Enter> until the 2-minute waiting period is up.
11. Press <Enter> to record the last tracing and save it as before by pressing <Esc> twice to return to the main menu, select <Data File/Disk Commands>, then select <Save Data Now in Memory>. <Name> the file after your subject followed by a 3 (e.g., *Bonnie3*), and press <Enter>.
12. You are now ready to analyze your data. The subject can remove and clean the electrodes.

Analysis

1. For each of the three recordings obtained, you will measure the time the heart spends in contraction (systole) and compare it with the time that the heart spends relaxing between beats (diastole). For our purposes, we will measure systole from the beginning of the P wave to the end of the QRS complex (see Figure 3.3). We will measure diastole from the end of the QRS complex to the beginning of P.



Figure 3.3. Measuring s ystole and diastole.

2. From the <Data File/Disk Commands> screen select <Load an Old Data File>. When it asks for the name of the file, load the first file you saved (e.g., *Bonnie1*).
3. Press <Esc> to return to the main menu then select <Review/Time Analysis>. Press <S> when you see a screen with three successive good tracings. Now for the measurement. Press the right arrow (→) and you will note that it moves a vertical line across the screen. Move the line until it is placed at the beginning of a “P” wave. Press <Z> to zero the measurement scale. Now use the same right arrow to move the line to the end of the QRS segment. The time (in seconds) displayed at the left under “Difference” is the time the heart spent in atrial and ventricular depolarization (“systole”). Record the value in Table 3.1 under Resting Beat 1, Systole, then

press <P> for print to obtain a record of this measurement for the group. Label this recording (e.g., “Resting – Bonnie1”) immediately after it is printed.

4. Without moving the line press <Z> to re-zero the measurement at the end of the QRS. Now move the arrow to the beginning of the next “P”. This S-P segment is the time the heart spends repolarizing and resting (“diastole”). Record the value in Table 3.1 under Resting Beat 1, Diastole. Press <P> to obtain a record of this measurement for the group and immediately label the paper. Press <Z> again and continue measuring “systole” then “diastole” for Beats 2 and 3 recording values in the “Resting” area of the chart. No more “resting” printouts will be required.
5. When finished with resting data, press <Esc> to return to the Review/Analyze Data menu, then <Esc> again to return to the main menu. Select <Data File>, then select <Load an Old Data File>. Now load your second set of recordings for analysis (e.g., *Bonnie2*).
6. Repeat steps 3 and 4 for this data and record the results in Table 3.1 under Post-Exercise. Follow step 5 to load data file 3 (e.g., *Bonnie3*) and repeat steps 4 and 5 for this last set of data recording results under the “After 2-minutes Rest” column.
7. You are now finished using the computer. Remove the data disk. Press <Esc> to return to the Cardiocomp-7 main menu. Select <Shutdown>. Finally, switch the junction box off and unplug the unit from the wall. Do not turn off each piece of equipment separately.
8. Be sure you have recorded your measurements in Table 3.1. The tracings you obtained should be turned in with your lab report.
9. Calculate the average time spent in systole then diastole for each condition (resting, post-exercise, and after 2 minutes rest) and record this value in Table 3.1.

Table 3.1. Data table for ECG.

Activity	Beat	Systole (P-S)		Diastole (S-P)	
		Time (seconds)	Average time (seconds)	Time (seconds)	Average time (seconds)
Resting	1				
	2				
	3				
Post-exercise	1				
	2				
	3				
After 2-minute rest	1				
	2				
	3				

10. Answer the following questions:

- (a) Did the average time for systole increase or decrease with exercise? By how many seconds?
- (b) Did average time for diastole increase or decrease? By how many seconds?
- (c) Which portion of the heart cycle showed more change with exercise, systole or diastole?
- (d) What factors might we consider when analyzing this difference?
- (e) Considering your results, can you think of reasons that unconditioned persons are told to limit their exercising heart rate to well under 180 beats per minute? (*Hint: What important things happen during diastole but not systole?*)

Exercise 2: Determination of Lung Volumes and Capacities

Ventilation of Human Lungs

Efficiency of gas exchange in organisms with lungs is ultimately dependent upon the organisms ability to move air in and out of the lungs. The total volume of air an individual's lungs can hold is dependent upon several factors: chest size, sex, and the health of the tissue. If part of the lung tissue is destroyed or if scar tissue forms making the tissue less elastic, the total lung capacity will decrease. A few of the common causes of decreased lung capacity are smoking, lack of exercise, emphysema, and pneumonia. Clinicians analyze the health of lung tissue, in part, by determining lung volumes and capacities (see Figure 3.4).

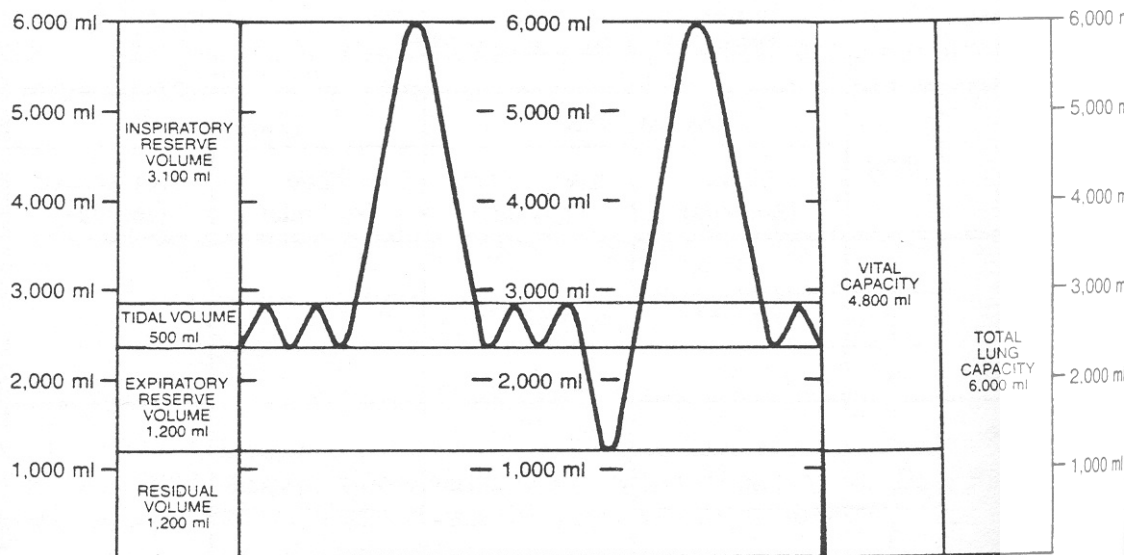


Figure 3.4. Lung volumes and capacities.

The *Vital Capacity* is the largest volume of air that can possibly be moved out of the lungs. It is measured from the top of a forced inhalation to the bottom of a forced exhalation. Forced exhalation such as this does not entirely collapse the lungs, however. A *Residual Capacity* of approximately 1 liter remains. Thus, *Total Lung Capacity* equals Vital Capacity plus Residual Capacity.

When at rest, an individual does not move the entire Vital Capacity with each breath. A smaller *Tidal Volume* of about 500 ml is moved with each breath at rest. Should more air be required after a normal inhalation, more air can be forcibly inhaled. This extra inhaled volume is termed the *Inspiratory Reserve Volume*. Similarly, after a normal exhalation, even more air can be forcibly exhaled. This extra exhaled volume is termed the *Expiratory Reserve Volume*.

Materials

Computer with Spirocomp attachments
 Phipps and Bird wet spirometer
 One way valve assembly soaking in 75% ethanol solution
 Container of mild soap solution to immerse valve assembly
 Disposable mouthpiece for each subject (one per group)
 Nose clip also soaking in ethanol solution

Introduction

You will measure lung volumes by using a computer attached to a wet spirometer that measures the volume of air exhaled into a drum suspended in water. A special one-way valve ensures that *you will only exhale into the device*. Each person will use a clean disposable mouthpiece and a nose clip that has been cleaned with alcohol or will otherwise pinch the nostrils to ensure that all exhaled air enters the device and does not escape undetected through the nostrils.

Procedure: Using the Computer

General Instructions

1. The computer and all components (screen, printer, etc.) are turned on simultaneously by plugging in the surge protector (junction box) and toggling the switch on top of the box to the left (toward the dot). Wait for the computer to “boot” and display the first menu.
2. At this time you should check to see that the printer has paper in it and that it is “on-line” (green light) and ready for use.
3. You will not need a student data disk in drive A for this exercise so you are now ready to use Spirocomp.

Note:

- The *up* and *down* arrow keys move the cursor up and down on the menus. Spirocomp uses only the arrows on the numeric key pad: up is “8”, down is “2”, right is “6”, and left is “4”.
- The *Enter* or return key is used to select the item the cursor is on.
- The *Escape* key is used to back up one step in the operation you are performing. Several “Esc” entries may be needed to return you to the main menu if you are several steps into an operation.

Instructions for Spirocomp Data Collection

1. Select <Spirocomp> from the first menu by pressing <Enter> then follow screen instructions:
 - (a) Press any key to begin.
 - (b) Press the <Num Lock> key in the upper left corner of the numeric key pad to turn off the “Num lock” light and press the grey <Caps lock> key at the left edge of the main keyboard to turn ON the “Caps lock” light. Then press <C> to continue. (If the computer did not let you continue then the “Caps lock” is still not activated. Try again).
 - (c) Press <Y> for yes, you do have a printer.
 - (d) Press <Y> for yes, you wish to use the transducer.
 - (e) Check to ensure that a grey wire from the back left side of your computer is connected to the back of the black dial arm that projects over the drum of the spirometer. Now press <Y>, your selections are correct.
2. Select <Experiment Menu>. Read down the menu to familiarize yourself with the choices:
 - (a) Reading from the bottom up, you already know to use the “Esc” key to back up to the previous menu. (Try it, if you wish).
 - (b) The next choice up, BTPS, is a correction for body temperature, atmospheric pressure, and saturation of exhaled air with water vapor. We will not alter this value.
 - (c) The third choice up changes tidal sensitivity of the equipment. The current setting of a 0.6-second pause being recognized as a change in breath direction and 0.3 liter as a breath should do for the entire exercise. Sensitivity of these settings should probably be increased if you were to measure a small child's breathing, but for our current population (i.e., you), the standard settings should suffice.
 - (d) Next is “calibrate Spirocomp transducer”. This procedure must be performed each time the computer equipment is turned off and on again or anytime the chain on the spirometer slips. Calibration is a procedure that allows the computer to interpret electrical signals as a specific measurement, in this case, volume. We will calibrate the equipment in a moment before we start collecting data.
 - (e) The remaining three choices at the top of the experiment menu refer to data collection. We will only use the first choice, “start a new group”. This choice tells the computer to abandon any data in its memory and start storing individual student records as a new group for group analysis. For this particular exercise we will be analyzing individual student records as they are collected so we will not use the program's storage or group analysis features.
3. Select <Calibrate Spirocomp Transducer> from the Experiment menu remembering to use the arrows on the numeric key pad.
 - (a) Make sure the air tube is open to room air (i.e., mouthpiece removed from air tube at the junction point marked with scratched rings or arrows).
 - (b) Have one partner press the white air drum to the bottom of the blue tub and lift the chain up from the black tube-like support post to relieve the tension on the dial. A second partner should watch the “Adjustment Number” on the computer screen, lift the chain from the dial wheel, and turn the dial until the adjustment number is between -100 and +100. Release the chain.

- (c) Adjust the black rubber pointer on the chain (and the small black circle that positions it) until the pointer is at the end of the scale near the dial and reads exactly “0”. Check to be sure that the adjustment number on the screen is still between -100 and +100 then press the *<space bar>*.
- (d) Remove the mouthpiece apparatus from the alcohol, swish it through the mild soap solution, then shake the loose water off. There is no need to dry it thoroughly since it actually works better when damp. Attach it to the air tube by matching the two pieces scratched or marked (i.e., attach to the flat drum side leaving the end with the “spoked wheel look” open.) Place a clean cardboard mouthpiece in the middle “T” portion of the apparatus.
- (e) Have the subject use gentle puffs to inflate the spirometer to exactly 5 liters as measured by the black rubber arrow on the spirometer arm. *Do not overinflate*. When exactly at 5 liters press the *<space bar>*. The equipment is now calibrated. You should not have to recalibrate unless the chain slips or you turn the computer off. As the drum becomes full of air, it sometimes tips over causing the chain to slip. One partner may have to gently stabilize the drum throughout the exercise to prevent chain slippage and the need to recalibrate. Empty the air from the drum by separating the valve apparatus from the air hose at the marked junction. Press down gently on the drum until it is at the bottom of the pan and reattach the valve apparatus.

4. You are now ready to perform the first measurements.

- (a) Enter the information about the subject as requested. Note that the computer advances automatically without your having to press *<Enter>*. The information requested will allow the computer to analyze the subject's records in comparison to healthy adult averages. If you make a mistake in data entry, continue until asked whether the information is correct. Answer *<N>* for no to change the answers or *<Y>* for yes to continue with data collection.
 - Enter the subject's initials.
 - Use the numbers on the main keyboard (not the numeric pad) to enter the subject's height in centimeters, if known, or height in whole inches followed by a quotation mark. For example, a height of 5 feet and 5.5 inches should be rounded to 5 feet and 6 inches and entered as *<66">*. The quotation mark (") is entered by holding down the shift key while pressing the (") key which is located next to the “Enter” key.
 - Respond to the age and gender questions.
 - When asked if the information is correct, *<N>* will let you change answers. *<Y>* will let you continue with data collection.
- (b) Each subject should use his/her own clean cardboard mouthpiece. (Write your name on yours to avoid confusion.) The subject should be calmly seated in a chair with his/her back straight. When measuring, the nostrils must be pinched closed (the subject may hold the nostrils closed or may use the nose clip — remove from alcohol, swish in soap solution, and dry) and the mouth must be tightly pressed to the mouthpiece so that no air escapes around the sides. The subject should not watch the screen or his/her lab partners since this distraction could alter breathing patterns.
- (c) Be sure the air drum is empty (separate valve apparatus at marks and press down on drum), reattach the valve apparatus and the subject's mouthpiece and prepare to measure *Tidal Volume*.

(Refer to the definition above if you are unsure of the volume to be measured.) The subject should breathe as normally as possible into the drum. It is very helpful to the partners if the subject will signal when he or she is inhaling. Raising and lowering the little finger along with the breathing cycle works very well. After two or three breaths, a partner should wait until the subject is inhaling then press <T> for Tidal Volume. The subject should continue to breathe as normally as possible. The computer will measure three complete cycles of breathing. The measurement is complete when the TV graph appears on the chart on the screen. *Separate the valve* apparatus at the marks, empty the air from the drum, then reattach the valve ready for the next measurement. If for some reason you wish to repeat this measurement, you may do so without leaving this screen. Simply breathe normally into the mouthpiece, press <T> again, and the computer will repeat the measurement replacing the old value with a new one.

(d) Empty the drum and prepare to measure *Expiratory Reserve Volume*. The subject should breathe normally into the spirometer for one breath. While the subject is in the middle of an inhalation, a partner should press <E>. The subject should continue to breathe as normally as possible. At the end of the second cycle, the screen will instruct the subject to pause at the end of the next normal exhale (meaning at the end of the third measured exhale). This instruction appears in plenty of time for a partner to read it to the subject so the subject need not be watching the screen. Almost instantly upon pausing, *the subject should hear a tone which is the signal to exhale* as *completely* as is possible. If you do not hear a tone, the subject paused one cycle too soon and the measurement will be invalid. Continue then repeat the measurement. The computer will display the results as ERV, expiratory reserve volume. Again, empty the drum and repeat the measurement until you are satisfied that it is as accurate as possible.

(e) Lastly for this subject, you will measure *Vital Capacity*. Be sure the drum is empty. This time the *subject should operate the keyboard* him/herself. Press <V> once to alert the computer to the measurement about to be taken. Next, have the subject inhale maximally then *simultaneously* press <V> again and forcefully exhale as *rapidly and completely* as possible into the spirometer. As before, the drum may be emptied and the measurement repeated until a valid measurement is obtained. Note that it is important that the subject exhale forcefully because the computer will calculate the percentage of the Vital Capacity that was exhaled in the first second (Forced Expiratory Volume₁), in the first two seconds (FEV₂), and in the first three seconds (FEV₃). *A normal FEV₁ should be between 75% and 85% of the VC. FEV₂ should be about 94% and FEV₃ about 97%. A low value indicates obstructive respiratory disorder such as asthma, bronchitis, or emphysema.* Once you are satisfied with the subject's values, remove the valve assembly from the air tube at the marked junction and place the valve assembly in the alcohol for a few minutes until the next subject is ready to use it. Press <P> to obtain a print copy of the subject's data for later analysis. You will have to wait for the printing to stop before you can proceed. One subject is all that is required for each group, but if more group members wish to try the measurements and time permits, you may press <N> to proceed with the next subject.

(f) For the remaining subjects of the group, follow the above protocol to:

- Enter subject data.
- Measure TV, ERV, and VC.
- Obtain a printed copy of the record for analysis.

Do not turn off the equipment as your group will have one more set of measurements to take in just a few minutes.

Analysis of Results

To complete Table 3.2, use your computer data record and follow the instructions in steps 1 to 5 below. Attach your printout to this lab before handing it in for evaluation.

Table 3.2. Data table for measured lung volumes and capacities.

Parameter	Your values	High/low/normal	Predicted values
Vital Capacity			
Tidal Volume			
Expiratory Reserve			
Inspiratory Reserve			

1. *Vital Capacity:* Use your computer data sheet to record your measured Vital Capacity (VC) and your predicted Vital Capacity (pVC) which the computer predicted based upon normal averages for your age and gender. A low Vital Capacity can indicate a loss of distensible lung tissue which could be caused by many disorders such as pneumonia or pulmonary congestion. A high value is often recorded by athletes. Record whether your value is high, low, or normal and attempt to explain any non-normal values.
2. *Tidal Volume:* Record your Tidal Volume in Table 3.2. This volume should be within the range of 10–20% of your Vital Capacity. Calculate this range and place these values in the chart under predicted values for Tidal Volume. Explain any values outside of normal range.
3. *Expiratory Reserve Volume:* Record your ERV in Table 3.2. For a predicted value use 25% of your Vital Capacity. The ERV can vary greatly and is especially affected by the position of the subject during measurement. Explain any non-normal results.
4. *Inspiratory Reserve Volume:* We did not measure IRV. The value merely appeared on your computer chart. How do you suppose this value was obtained? Verify your guess by performing the computation. Record your IRV in Table 3.2 and use 60–70% of Vital Capacity as the predicted normal range. Explain any non-normal results.
5. If you were to run in place for 2 minutes then were to redetermine the values obtained above, which values do you think would increase? Which would decrease? And which would stay the same? Plan how you will take these measurements, then select at least one group member to run in place (or run around the hallway outside) until breathing is considerably elevated. Then, quickly and efficiently, perform the measurements to see if you predicted correctly. Complete Table 3.3 by using *this subject's normal values* and the post-exercise values. Why is it necessary to use this subject's normal data? You are now done with the computer. Press <Esc> twice to return to the main menu then select <Shutdown>. Turn off the power at the junction box. Do not switch off each component individually.

Table 3.3. Lung volumes and capacities pre- and post-exercise.

Parameter	Normal	Change	After exercise
Vital Capacity			
Tidal Volume			
Expiratory Reserve			
Inspiratory Reserve			

Notes for the Instructor

Although the equipment for this exercise is a major financial investment, it is well worth considering for a multitude of reasons. The student interest these exercises generate is exceptionally high. Students are interested in studying themselves and they are interested in computers. This combination motivates students to persevere through what appears to be relatively complex directions with relative ease. These exercises use computers as measuring tools, a change from the word processing, calculating, or simulation functions usually associated with introductory computer exercises and an important mental distinction for students to make.

ECG Exercise

Sometimes students have trouble obtaining a clear “noise-free” tracing to measure. This problem is usually solved by making sure all wires are securely snapped in place, arms and legs are cleanly scrubbed with alcohol, and contact with the plate is good by using the moist alcohol swab between the plate and the student's limb. In addition, the student must lie motionless because body muscles generate electrical signals when contracted just as the heart muscle does. If the above suggestions are all followed and the recording is still unclear, it may be that the room has older, less shielded wiring and “60-cycle” interference is being picked up from the lights. Try switching nearby lights off or moving to a room with less electrical equipment.

When measuring ECGs students should find that as heart rate increases the diastole or resting portion of the beat decreases more than does the systole or contraction phase. This is a significant occurrence because the heart requires time to push or move blood during systole and cannot be overrushed. In addition, during diastole, the heart needs time to permit blood to enter the chambers or the ventricles will not have enough volume inside to pump blood out. The diastolic time is also used to supply nourishment to the hard working ventricle through the coronary arteries because systolic contraction is so strong that blood is forced from the coronaries on the left side. As a result, as heart rate increases, the left ventricle actually has less time in which it can receive the nourishment it needs. These facts explain why physicians caution against permitting heart rate to increase above recommended levels when exercising.

We like to conclude this exercise with a student discussion of problems the students observe in measuring and analyzing the ECG. First, we hope the students note that they must develop consistency in where they measure the beginning and end of each segment or they will introduce errors. Second, we hope the students note that the resting heart spends more time in diastole than in systole so a larger absolute change in diastole may not actually be a larger relative change. A more meaningful measurement they could suggest would be percentage changes in systole compared with percentage changes in diastole. An individual instructor may wish to change the written exercise to incorporate this change rather than relying on a post-exercise discussion.

Spirometry Exercise

There are two major problems students encounter when performing the spirometry exercise. First, when the drum is completely filled to the 5-liter mark as occurs during equipment calibration and sometimes when measuring Vital Capacity, the air drum may tip to the side causing the chain to slip from the measurement wheel that attaches to the computer interface. When this occurs, the

equipment must be recalibrated and all measurements repeated. A suggestion would be to start with the equipment on a level table and to have one member of each student group gently stabilize the drum with a finger or two as the spirometer is inflated.

A second problem occurs when the group member operating the computer attempts to determine whether the subject is inhaling or exhaling. It is not always obvious, especially when the subject is breathing quietly. This explains the suggestion written into the exercise that the subject signal, perhaps by moving a finger up then down as they inhale then exhale.

Normal and abnormal values for this exercise are briefly explained in the discussion that follows Table 3.2. It is particularly significant to note differences in forced expiratory volumes that indicate varying degrees of asthma or bronchitis. As a person forcibly exhales, the contracting chest wall indirectly applies pressure not only to the alveoli but also to the bronchioles. If the bronchioles are narrower than normal due to asthma or bronchitis, the force may cause the bronchioles to collapse, trapping air in the lung, decreasing both Vital Capacity and the percentage of the Vital Capacity exhaled in the first seconds.

A second aspect to this exercise that is particularly significant is the student predictions and plans for measuring post-exercise changes. Tidal Volume should increase markedly but Vital Capacity should not change. As a result, the Reserve Capacities should decrease to permit the increase in Tidal Volume. If students are inefficient at planning their post-exercise measurements, the subject will have recovered before the measurements are complete. Perhaps most efficient would be to measure Tidal Volume first since it is a relatively quick measurement and it is expected to change significantly. Arguments could be made for measuring either Vital Capacity next (its a faster, easier measurement to take) or Expiratory Reserve Volume next (ERV is expected to change more than VC). We would probably pick Vital Capacity before Expiratory Reserve Volume because speed of measurement is such an important factor. In either case, the planning and reasoning process of the student is the critical factor in the exercise.

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APPENDIX A

Investigational Exercise

Exercise 3: Design Your Own Exercise

1. You now understand how to use computer-interfaced tools to measure ECGs and lung volumes and capacities. Describe a problem you wish to investigate using this equipment.
2. What variables will you need to control?
3. Plan how you will take accurate and timely measurements. Describe the procedure you will follow.
4. Design a chart for data entry that will help you interpret your results.

APPENDIX B

Equipment

Physiological Equipment

The following computer-interfaced physiological equipment is available from Intelitool (Box 459, Batavia, IL 60510-0459, 1-800-227-3805):

1. *ECG exercise*: Cardiocomp-7 package (includes software, seven lead data acquisition board, five electrodes and cables, electrode cable junction box, electrode gel, electrode washers, and user and lab manuals). There is selection of three different models for different prices. We selected the intermediate model (Cardiocomp-7) which uses seven different leads and permits simultaneous ECG recording from three different leads and subsequent calculation of the vectogram.
2. *Spirometry exercise*: Complete Spirocomp package (includes a Phipps and Bird wet spirometer with a spirometer-to-micro-computer interface, one-way mouthpiece valve, software, and user and lab manuals). The equipment as supplied is not the correct size for using disposable mouthpieces. We replaced the "T" apparatus on the one-way valve apparatus with a schedule 40 PVC 1" × 1" × 0.75" lawn sprinkler "T" obtained from a local hardware store. This junction permits use of cardboard mouthpieces such as those from Fisher Scientific Co. (4901 West LeMoyne St., Chicago, IL 60651), for example, catalog #S17046AND.

Computer Equipment

Intelitool products will run on a variety of computers including the Apple II series and IBM-PC compatible machines. Products for Macintosh were not available at the time we were selecting equipment although these products are under development. We selected IBM 386SX clones with VGA color monitors because some of the Intelitool products require a game port and are not guaranteed to operate effectively if the operating system runs at speeds over 20 Mhz.

In addition to the basic computer, we purchased a dot matrix printer for each station and a cart to make each computer/printer into a mobile workstation. A surge protector junction box with switch protects the equipment and also permits students to wheel the station into position, plug in the junction box, and switch the entire station on with one switch.

We also recommend a hard disk drive in addition to the floppy drive that is needed for the student data disk. Many students will not be familiar with the computer operating system. A computer technician can load all needed programs on the hard drive and design a menu that appears when the power is switched on that will run each selected program with the push of a single button.

A print buffer is also a desirable addition. When students print a data file, the computer "locks up" until the entire file is printed. A buffer would permit the students to continue with other measurements while printing proceeds.