Lab Handbook

BME 221
Undergraduate Laboratory

Fall Semester

DEPARTMENT OF BIOMEDICAL ENGINEERING
THE UNIVERSITY OF TEXAS AT AUSTIN

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Revision A

Table of Contents

BME UG Lab Policies

Biosensors

Biomaterials

Metabolic Rate

Biopotentials

Appendix

BIOMEDICAL ENGINEERING
THE UNIVERSITY OF TEXAS AT AUSTIN

BME UG Lab Policies

This section contains information necessary for getting started in the BME undergraduate laboratory. Laboratory safety is everyone's priority, and you must become familiar with the laboratory safety policies and practices. The section, "Before You Can Work in the Laboratory" on page 1-2, describes what you must do before working in the laboratory.

The last half of this chapter provides the Material Safety Data Sheets (MSDS) for the chemicals that you may be working with in this laboratory. Material Safety Data Sheets are extremely important in the safe handling of hazardous substances. It is your responsibility to become familiar with the specific hazards and safe handling of these chemicals—as well as the rest of the materials described in the MSDS. A glossary of MSDS terms appears at the end of this chapter.

SECTION CONTENTS

BEFORE YOU CAN WORK IN THE LABORATORY

Before you are allowed to work in the laboratory, you must first:

- Read the *Laboratory Handbook* in its entirety.
- Participate in the *Orientation and General Lab Safety* brief provided by the University Laboratories Safety Officer during the first class lecture.
- Sign and submit the *BME UG Lab Undergraduate Student Contract* with an initialized copy of "BME UG Lab Protocol" on page 1-3.

These prerequisites are mandatory and no exceptions will be made. See "BME 221 Student Contract" on page 1-6 for a copy of the contract you will be required to sign and submit to acknowledge your compliance with the laboratory prerequisites. Refer to http://www.utexas.edu/safety/ehs/train/courses.html for further information regarding online safety training.

LAB SAFETY

Safety is serious business. Any violation of laboratory protocol or general safety practice may result in an F and/or dismissal from the course. The laboratory space is limited, and your actions can potentially endanger others. Always be considerate of others around you.

At all times while you are in the laboratory, you are accountable for the laboratory protocol and safety practices in the following sections:

- "BME UG Lab Protocol" on page 1-3
- "General Laboratory Safety" on page 1-4

BME UG Lab Protocol

Due to the potentially hazardous nature of laboratory work, safe practices are critical to ensure your safe participation in the laboratory course. Any violation of lab protocol or general lab safety practice ("General Laboratory Safety" on page 1-4) may result in an *F* and/or dismissal from the laboratory course.

Read the following table thoroughly, placing your initials next to each box to indicate that you have read and understood the statement. Then turn a copy in with your Student Contract (see "BME 221 Student Contract" on page 1-6 for a checklist of materials that must be turned in before you may work in the lab).

BME UG Laboratory Protocol	Your Initials
When you are in the laboratory, your teaching assistant (TA) is your lab supervisor.	
Before you start any work in the lab, ensure you are familiar with the equipment you will be using—as well as the procedures for operating the equipment. Locate and read the Material Safety Data Sheets (MSDS) for the chemicals you will be using.	
Wear long pants to avoid burns and contact with hazardous chemicals. Shorts, skirts, tank tops, sandals or open-toe shoes are not allowed, and anyone wearing these items will *not* be allowed in the laboratory.	
Food, drinks, candy, or chewing gum are strictly prohibited in the laboratory.	
Never mouth pipette anything.	
Do not wear lab coats, gloves, or other personal protective clothing out of the lab.	
Always wash your hands after working with chemicals and before leaving the lab.	
Misconduct will not be tolerated at any time in the laboratory.	
If you wear contact lenses, you are required to wear eye goggles when working with laboratory chemicals. In general, you should not wear contact lenses in the laboratory, since chemicals or particulates can get caught between the lens and the eye causing severe damage to your eye.	
Clean up after yourself. Label all containers clearly, include your name and the contents of the container.	

General Laboratory Safety

In addition to "BME UG Lab Protocol" on page 1-3, you must observe the following general laboratory safety practices whenever applicable.

Lab Cleanliness

You are accountable for keeping the lab clean.

- Always leave the benchtop clean.
- Put all chemicals and lab materials away when you are finished.
- Throw away paper towels and Kimwipes that you have used.
- Double-check your lab station before you leave to ensure that you are leaving the station in a clean and organized fashion for the next group.

Labels

You must always label any tube, beaker, petri dish, or vial with your initials, the date, and contents *before* use—*even if it's water*. Failure to label containers leads to unknown chemicals, which in turn creates many problems for chemical disposal crews.

Lab Security

Your assistance in keeping the lab secure is essential. Immediately report anything suspicious to Jim Pollard, your TA, or the campus police (#1-4441).

- When the lab is unoccupied, the door must remain closed and locked at all times.
- No lab equipment may leave the lab at any time.

Good Laboratory Practices

1. Avoid loose clothing such as dresses, neckties, and dangling jewelry which can get caught in equipment. Long hair is also a risk around some equipment and should be secured as a precaution.
2. Know where to find and how to operate fire extinguishers, safety showers, eye fountains, and electrical shutoff devices.
3. Materials Safety Data Sheets (MSDS) must be brought into the lab with any chemical.
   - If you pick up a chemical yourself, you may obtain the MSDS when you pick up the chemical from the stockroom. The MSDS should be permanently placed in the yellow binder in the lab.
   - You should always familiarize yourself with the MSDS before using any chemicals.

4. Ventilation hoods should be used when transferring volatile or toxic chemicals.
5. Flammable liquids should be stored in the Flammable Liquid Storage Cabinet when not in use.
   - Minimize the amount of such materials brought into the lab.
   - When working with flammable liquids, keep the liquid in a hood and return the liquid to the *Flammable Liquid Storage Cabinet* at the end of a lab session.
6. Electrical hazards should be eliminated.
   - Frayed or otherwise hazardous electrical cords should be reported and replaced or repaired.
   - Flammable solvents should be kept away from electrical equipment.
   - Electrical equipment should be grounded.
7. Spills must be cleaned up immediately. This includes water, solvents, mercury (broken thermometer), or any other laboratory chemicals. See your lab TA for assistance.
8. Hazardous waste must be properly labeled and presented to the laboratory manager for disposal. This includes organic liquids, flammable materials, toxic chemicals, and solutions of extreme acidity or basicity. *Never* pour these solutions down the drain.

BME 221 STUDENT CONTRACT

Each semester before you may work in the lab, you must submit the following contract and have it initialed by Jim Pollard and signed by Dr. Brannon-Peppas.

Your Information

Name:_____ SSN#:_____

Current Semester & Year:_____ Course:_____

E-Mail:_____ Phone:_____

Emergency Contact Information

Contact Name:_____ Relationship to You:_____

Phone Number:_____ E-Mail:_____

Address:_____

Required Training for All Students	Date Completed	Initials (Pollard)
Read, initial, and submit copy of "BME UG Lab Protocol" on page 1-3		
Attend *Orientation & General Lab Safety Training* (UT Laboratories Safety Officer)	1st Lecture	
Complete *Hazard Communication* (OH 101)[Note 1]		
Complete *Laboratory Safety* (OH 201)[Note 1]		

Note 1 **These non-mandatory courses are offered online by the University of Texas. See http://www.utexas.edu/safety/ehs/train/courses.html for course details.**

Student Signature:_____

Lab Supervisor Signature:_____

Dr. Lisa Brannon-Peppas

LAB HOURS

Due to fire code restrictions on laboratory occupancy, only one section at a time may use the lab. That is, you may only access the lab when your section is scheduled. *You will not have access the laboratory during any other time*.

The laboratory schedule for the Fall semester is as follows:

- Lecture (all sections): Wednesday 2:00 to 3:00
- Section 1: Monday 10:00 to 1:00
- Section 2: Tuesday 9:30 to 12:30
- Section 3: Wednesday 10:00 to 1:00
- Section 4: Friday 10:00 to 1:00

LABORATORY SCHEDULE

Monday Lab Section Schedule

Monday labs are held in CPE 1.120 from 10 AM to 1 PM on Mondays.

Note: The Monday lab section is required to meet on Wednesday, September 8th.

MON		Assignment	Biomaterials	Biopotentials	Metabolism
M	**8/30**	Biomedical Device Analysis			
M	**9/6**	***** Labor Day Holiday (No Labs) *****			
W	**9/8**	Glucose Sensor [**Monday Section Make-Up Day**]			
M	**9/13**	Glucose Sensor Memo Due	**M1**	**M2**	**M3**
M	**9/20**		**M1**	**M2**	**M3**
M	**9/27**	Lab 1 Progress Report Due	**M1**	**M2**	**M3**
M	**10/4**		**M1**	**M2**	**M3**
M	**10/11**	Lab Report 1 Due	**M2**	**M3**	**M1**
M	**10/18**		**M2**	**M3**	**M1**
M	**10/25**	Lab 2 Progress Report Due	**M2**	**M3**	**M1**
M	**11/1**		**M2**	**M3**	**M1**
M	**11/8**	Lab Report 2 Due	**M3**	**M1**	**M2**
M	**11/15**		**M3**	**M1**	**M2**
M	**11/22**	Lab 3 Progress Report Due	**M3**	**M1**	**M2**
M	**11/29**		**M3**	**M1**	**M2**
M	**12/6**	Lab Report 3 Due by 10 am			

Tuesday Lab Section Schedule

Tuesday labs are held in CPE 1.120 from 9:30 AM to 12:30 PM on Tuesdays.

TUE		Assignment	Biomaterials	Biopotentials	Metabolism
T	**8/31**	Biomedical Device Analysis			
T	**9/7**	Glucose Sensor			
T	**9/14**	Glucose Sensor Memo Due	**T1**	**T2**	**T3**
T	**9/21**		**T1**	**T2**	**T3**
T	**9/28**	Lab 1 Progress Report Due	**T1**	**T2**	**T3**
T	**10/5**		**T1**	**T2**	**T3**
T	**10/12**	Lab Report 1 Due	**T2**	**T3**	**T1**
T	**10/19**		**T2**	**T3**	**T1**
T	**10/26**	Lab 2 Progress Report Due	**T2**	**T3**	**T1**
T	**11/2**		**T2**	**T3**	**T1**
T	**11/9**	Lab Report 2 Due	**T3**	**T1**	**T2**
T	**11/16**		**T3**	**T1**	**T2**
T	**11/23**	Lab 3 Progress Report Due	**T3**	**T1**	**T2**
T	**11/30**		**T3**	**T1**	**T2**
T	**12/7**	Lab Report 3 Due by 10 am			

Wednesday Lab Section Schedule

Wednesday labs are held in CPE 1.120 from 10 AM to 1 PM on Wednesdays.

Note: The Wednesday lab section does *NOT* meet on Wednesday, September 8th.

WED		Assignment	Biomaterials	Biopotentials	Metabolism
W	**8/25**	Biomedical Device Analysis			
W	**9/1**	Glucose Sensor			
W	**9/8**	**No Wednesday Section LAB** Glucose Sensor Memo Due			
W	**9/15**		**W1**	**W2**	**W3**
W	**9/22**		**W1**	**W2**	**W3**
W	**9/29**	Lab 1 Progress Report Due	**W1**	**W2**	**W3**
W	**10/6**		**W1**	**W2**	**W3**
W	**10/13**	Lab Report 1 Due	**W2**	**W3**	**W1**
W	**10/20**		**W2**	**W3**	**W1**
W	**10/27**	Lab 2 Progress Report Due	**W2**	**W3**	**W1**
W	**11/3**		**W2**	**W3**	**W1**
W	**11/10**	Lab Report 2 Due	**W3**	**W1**	**W2**
W	**11/17**		**W3**	**W1**	**W2**
W	**11/24**	Lab 3 Progress Report Due	**W3**	**W1**	**W2**
W	**12/1**		**W3**	**W1**	**W2**
W	**12/8**	Lab Report 3 Due by 10 am			

Friday Lab Section Schedule

Friday labs are held in CPE 1.120 from 10 AM to 1 PM on Fridays.

FRI		Assignment	Biomaterials	Biopotentials	Metabolism
F	**8/27**	Biomedical Device Analysis			
F	**9/3**	Glucose Sensor			
F	**9/10**	Glucose Sensor Memo Due	**F1**	**F2**	**F3**
F	**9/17**		**F1**	**F2**	**F3**
F	**9/24**	Lab 1 Progress Report Due	**F1**	**F2**	**F3**
F	**10/1**		**F1**	**F2**	**F3**
F	**10/8**	Lab Report 1 Due	**F2**	**F3**	**F1**
F	**10/15**		**F2**	**F3**	**F1**
F	**10/22**	Lab 2 Progress Report Due	**F2**	**F3**	**F1**
F	**10/29**		**F2**	**F3**	**F1**
F	**11/5**	Lab Report 2 Due	**F3**	**F1**	**F2**
F	**11/12**		**F3**	**F1**	**F2**
F	**11/19**	Lab 3 Progress Report Due	**F3**	**F1**	**F2**
F	**11/26**	***** Thanksgiving Holiday (No Lab) *****			
F	**12/03**		**F3**	**F1**	**F2**
F	**12/10**	Lab Report 3 Due by 10 am			

CONTACT INFORMATION

You may contact laboratory personnel by phone or e-mail, if you require contact outside of normal classroom hours. As a safety precaution, please ensure that your e-mail messages include a descriptive subject heading.

Course Instructor

Lisa Brannon-Peppas, Ph.D.
CPE 3.168a 491-4348
peppas@mail.utexas.edu
office hours: Monday and Tuesday 2:00 to 3:00, or by appointment

Special Projects Coordinator/Lab Manager

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MATERIAL SAFETY DATA SHEETS

The following section provides a list of chemicals that you may be working with in our lab. The material safety data sheets (MSDS) for these chemicals are located in the MSDS notebook located in the laboratory, as well as available on the BME UG Lab web site as PDFs. "MSDS Glossary" on page 1-12 provides definitions for terms used in the MSDS.

You may be required to work with some or all of the following substances:

- Ascorbic Acid
- Galactose
- Gelatin from Porcine Skin, Type A
- Glucose
- Hydroxylapatite
- Maltose

It is your responsibility to read the MSDS information for these chemicals. Do *not* attempt to work with these chemicals until you have read the MSDS information and thoroughly understand the risks.

You may view or download the MSDS in PDF format at:

http://www.bme.utexas.edu/ugrad/UGLab/msds.html

Material Safety Data Sheet

L-Ascorbic acid

ACC# 12385

Section 1 - Chemical Product and Company Identification

MSDS Name: L-Ascorbic acid
Catalog Numbers: S71917, S71918, A61-100, A61-25, A6125LC, A62-12, A62-212, A62-25, A62-500, AA245-C, BP351-500, NC9557991, XXA61-7KG
Synonyms: Ascorbic acid; 3-Keto-L-glucofuranolactone; Vitamin C; L-3-keto-threo-hexuronic acid lactone.
Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
50-81-7	L-Ascorbic acid	99	200-066-2

Hazard Symbols: None listed.
Risk Phrases: None listed.

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white to yellow crystals. **Caution!** Light sensitive. Air sensitive. This is expected to be a low hazard for usual industrial handling. May cause eye, skin, and respiratory tract irritation. Strong reducing agent. Fire and explosion risk in contact with oxidizing agents.
Target Organs: None.

Potential Health Effects
Eye: May cause eye irritation.

Skin: May cause skin irritation. Low hazard for usual industrial handling.
Ingestion: Ingestion of large amounts may cause gastrointestinal irritation. Low hazard for usual industrial handling. Large doses may cause diarrhea and acidification of the urine which may cause stones in the urinary tract.
Inhalation: May cause respiratory tract irritation. Low hazard for usual industrial handling.
Chronic: No information found.

Section 4 - First Aid Measures

Eyes: Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. If irritation develops, get medical aid.
Skin: Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists. Wash clothing before reuse.
Ingestion: Never give anything by mouth to an unconscious person. Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water. Wash mouth out with water. Get medical aid if irritation or symptoms occur.
Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. This material in sufficient quantity and reduced particle size is capable of creating a dust explosion. Powerful reducing agent.
Extinguishing Media: Use extinguishing media most appropriate for the surrounding fire.
Flash Point: Not available.
Autoignition Temperature: 1220 deg F (660.00 deg C)
Explosion Limits, Lower: Not available.
Upper: Not available.
NFPA Rating: (estimated) Health: 1; Flammability: 1; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Use with adequate ventilation. Avoid breathing dust.
Storage: Store in a cool, dry, well-ventilated area away from incompatible substances. Store protected from moisture. Store protected from light. Store under an inert atmosphere.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
L-Ascorbic acid	none listed	none listed	none listed

OSHA Vacated PELs: L-Ascorbic acid: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.
Skin: Wear appropriate protective gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to minimize contact with skin.
Respirators: A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements or European Standard EN 149 must be followed whenever workplace conditions warrant a respirator's use.

Section 9 - Physical and Chemical Properties

Physical State: Crystals
Appearance: white to yellow
Odor: none reported
pH: 2.1-2.6 (5% soln)
Vapor Pressure: Not available.
Vapor Density: Not available.
Evaporation Rate: Not available.
Viscosity: Not available.
Boiling Point: Not available.
Freezing/Melting Point:190 deg C (dec)
Decomposition Temperature:190 deg C
Solubility: Soluble.
Specific Gravity/Density:1.65

Molecular Formula:C6H8O6
Molecular Weight:176.13

Section 10 - Stability and Reactivity

Chemical Stability: Stable at room temperature in closed containers under normal storage and handling conditions. Stable to air when dry; aqueous solutions are rapidly oxidized by air.
Conditions to Avoid: Light, dust generation, excess heat, moist air.
Incompatibilities with Other Materials: Strong oxidizing agents.
Hazardous Decomposition Products: Carbon monoxide, carbon dioxide.
Hazardous Polymerization: Will not occur.

Section 11 - Toxicological Information

RTECS#:
CAS# 50-81-7: CI7650000
LD50/LC50:
CAS# 50-81-7:
Oral, mouse: LD50 = 3367 mg/kg;
Oral, rat: LD50 = 11900 mg/kg;
Carcinogenicity:
CAS# 50-81-7: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
Epidemiology: No information available.
Teratogenicity: Teratogenic effects have occurred in humans.
Reproductive Effects: No information available.
Neurotoxicity: No information available.
Mutagenicity: No information available.
Other Studies: See actual entry in RTECS for complete information.

Section 12 - Ecological Information

No information available.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	IATA	RID/ADR	IMO	Canada TDG
Shipping Name:	No information available.				No information available.
Hazard Class:					
UN Number:					
Packing Group:					

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 50-81-7 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.
Section 12b
None of the chemicals are listed under TSCA Section 12b.
TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.
SARA

CERCLA Hazardous Substances and corresponding RQs
None of the chemicals in this material have an RQ.
SARA Section 302 Extremely Hazardous Substances
None of the chemicals in this product have a TPQ.
Section 313
No chemicals are reportable under Section 313.
Clean Air Act:
This material does not contain any hazardous air pollutants. This material does not contain any Class 1 Ozone depletors. This material does not contain any Class 2 Ozone depletors.
Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA. None of the chemicals in this product are listed as Priority Pollutants under the CWA. None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 50-81-7 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

Not available.

Risk Phrases:

Safety Phrases:

S 24/25 Avoid contact with skin and eyes.

WGK (Water Danger/Protection)

CAS# 50-81-7: 0

Canada - DSL/NDSL

CAS# 50-81-7 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of Not controlled..

Canadian Ingredient Disclosure List

Exposure Limits

Section 16 - Additional Information

MSDS Creation Date: 7/13/1999
Revision #4 Date: 4/08/2003

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Material Safety Data Sheet

Dextrose Anhydrous

ACC# 06365

Section 1 - Chemical Product and Company Identification

MSDS Name: Dextrose Anhydrous
Catalog Numbers: AC410950010, S73415, S73418, S73418-1, S73418-2, S734181, S734182, BP350-1, BP350-500, D14212, D1450, D14500, D16-1, D16-10, D16-3, D16-50, D16-500, D19-12, NC9519486, NC9539130, NC9614447, NC9823372
Synonyms: Corn Sugar; Glucose; D-Glucose; Grape Sugar.
Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
50-99-7	Glucose	>99	200-075-1

Hazard Symbols: None listed.
Risk Phrases: None listed.

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white solid. **Caution!** This is expected to be a low hazard for usual industrial handling. May cause eye and skin irritation. May cause respiratory and digestive tract irritation.
Target Organs: No data found.

Potential Health Effects

Eye: May cause eye irritation.
Skin: May cause skin irritation. Low hazard for usual industrial handling.

Ingestion: No hazard expected in normal industrial use. May cause irritation of the digestive tract.
Inhalation: No hazard expected in normal industrial use. May cause respiratory tract irritation.
Chronic: No information found.

Section 4 - First Aid Measures

Eyes: Gently lift eyelids and flush continuously with water. If irritation develops, get medical aid.
Skin: Get medical aid if irritation develops or persists. Wash clothing before reuse. Flush skin with plenty of soap and water.
Ingestion: Get medical aid. Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water. Get medical aid if irritation or symptoms occur.
Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Dusts at sufficient concentrations can form explosive mixtures with air. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.
Extinguishing Media: Use agent most appropriate to extinguish fire. Use water spray, dry chemical, carbon dioxide, or appropriate foam.
Flash Point: Not applicable.
Autoignition Temperature: Not applicable.
Explosion Limits, Lower: Not available.
Upper: Not available.
NFPA Rating: (estimated) Health: 0; Flammability: 0; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Avoid ingestion and inhalation.
Storage: Store in a cool, dry, well-ventilated area away from incompatible substances.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Glucose	none listed	none listed	none listed

OSHA Vacated PELs: Glucose: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.
Skin: Protective garments not normally required.
Clothing: Protective garments not normally required.
Respirators: A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements or European Standard EN 149 must be followed whenever workplace conditions warrant a respirator's use.

Section 9 - Physical and Chemical Properties

Physical State: Solid
Appearance: white
Odor: odorless
pH: 5.9 (0.5M)
Vapor Pressure: Negligible.
Vapor Density: Not applicable.
Evaporation Rate: Negligible.
Viscosity: Not applicable.
Boiling Point: Not available.
Freezing/Melting Point:295 deg F
Decomposition Temperature: Not available.
Solubility: Soluble in water.
Specific Gravity/Density:1.54 (water=1)
Molecular Formula:C6H12O6
Molecular Weight:180.0804

Section 10 - Stability and Reactivity

Chemical Stability: Stable under normal temperatures and pressures.
Conditions to Avoid: Incompatible materials, dust generation, excess heat.
Incompatibilities with Other Materials: Oxidizing agents.
Hazardous Decomposition Products: Carbon monoxide, irritating and toxic fumes and gases, carbon dioxide.
Hazardous Polymerization: Has not been reported.

Section 11 - Toxicological Information

RTECS#:
CAS# 50-99-7: LZ6600000
LD50/LC50:
CAS# 50-99-7:
Oral, rat: LD50 = 25800 mg/kg;
Carcinogenicity:
CAS# 50-99-7: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
Epidemiology: No information available.
Teratogenicity: No information available.
Reproductive Effects: No information available.
Neurotoxicity: No information available.
Mutagenicity: No information available.
Other Studies: See actual entry in RTECS for complete information.

Section 12 - Ecological Information

No information available.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	IATA	RID/ADR	IMO	Canada TDG
Shipping Name:	No information available.				No information available.
Hazard Class:					
UN Number:					
Packing Group:					

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 50-99-7 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.
Section 12b
None of the chemicals are listed under TSCA Section 12b.
TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.
SARA

CERCLA Hazardous Substances and corresponding RQs
None of the chemicals in this material have an RQ.
SARA Section 302 Extremely Hazardous Substances
None of the chemicals in this product have a TPQ.
SARA Codes
CAS # 50-99-7: flammable.
Section 313
No chemicals are reportable under Section 313.
Clean Air Act:
This material does not contain any hazardous air pollutants. This material does not contain any Class 1 Ozone depletors. This material does not contain any Class 2 Ozone depletors.
Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA. None of the chemicals in this product are listed as Priority Pollutants under the CWA. None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
OSHA:
None of the chemicals in this product are considered highly hazardous by OSHA.
STATE

CAS# 50-99-7 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:
Not available.

Risk Phrases:

Safety Phrases:

WGK (Water Danger/Protection)
CAS# 50-99-7: 0

Canada - DSL/NDSL
CAS# 50-99-7 is listed on Canada's DSL List.

Canada - WHMIS
This product has a WHMIS classification of Not controlled..

Canadian Ingredient Disclosure List

Exposure Limits

Section 16 - Additional Information

MSDS Creation Date: 7/14/1999
Revision #2 Date: 3/18/2003

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Material Safety Data Sheet
D-(+)-Galactose Anhydrous

ACC# 10265

Section 1 - Chemical Product and Company Identification

MSDS Name: D-(+)-Galactose Anhydrous
Catalog Numbers: S80022, BP656-500, G1-100
Synonyms: D-Galactopyranose
Company Identification:
Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410
For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
59-23-4	D-Galactose	ca. 100%	200-416-4

Hazard Symbols: None listed.
Risk Phrases: None listed.

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white. **Caution!** This substance has caused adverse reproductive and fetal effects in animals. This is expected to be a low hazard for usual industrial handling. May cause eye and skin irritation. May cause respiratory and digestive tract irritation.
Target Organs: None.

Potential Health Effects
Eye: May cause eye irritation. Dust may cause mechanical irritation.
Skin: May cause skin irritation. Low hazard for usual industrial handling.
Ingestion: May cause gastrointestinal irritation with nausea, vomiting and diarrhea. Low hazard

for usual industrial handling.
Inhalation: May cause respiratory tract irritation. Low hazard for usual industrial handling.
Chronic: No information found.

Section 4 - First Aid Measures

Eyes: Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. If irritation develops, get medical aid.
Skin: Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists. Wash clothing before reuse.
Ingestion: If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid.
Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.
Notes to Physician: Treat symptomatically.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Dusts at sufficient concentrations can form explosive mixtures with air. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Vapors may be heavier than air. They can spread along the ground and collect in low or confined areas.
Extinguishing Media: Use agent most appropriate to extinguish fire. Use water spray, dry chemical, carbon dioxide, or appropriate foam.
Flash Point: Not applicable.
Autoignition Temperature: Not applicable.
Explosion Limits, Lower: Not available.
Upper: Not available.
NFPA Rating: (estimated) Health: 1; Flammability: 0; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Avoid ingestion and inhalation.
Storage: Store in a tightly closed container. Keep from contact with oxidizing materials. Store in a cool, dry, well-ventilated area away from incompatible substances.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
D-Galactose	none listed	none listed	none listed

OSHA Vacated PELs: D-Galactose: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.
Skin: Wear appropriate protective gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to prevent skin exposure.
Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

Section 9 - Physical and Chemical Properties

Physical State: Solid
Appearance: white
Odor: odorless
pH: Not available.
Vapor Pressure: Negligible.
Vapor Density: 6.2
Evaporation Rate: Negligible.
Viscosity: Not available.
Boiling Point: Not available.
Freezing/Melting Point:167 deg C
Decomposition Temperature: Not available.
Solubility: 680 g/l (25 C) in water.
Specific Gravity/Density: Not available.
Molecular Formula:C6H12O6
Molecular Weight:180.0804

Section 10 - Stability and Reactivity

Chemical Stability: Stable under normal temperatures and pressures.
Conditions to Avoid: Incompatible materials, dust generation, excess heat.
Incompatibilities with Other Materials: Oxidizing agents.
Hazardous Decomposition Products: Carbon monoxide, irritating and toxic fumes and gases, carbon dioxide.
Hazardous Polymerization: Has not been reported.

Section 11 - Toxicological Information

RTECS#:
CAS# 59-23-4: LW5490000
LD50/LC50:
Not available.

Carcinogenicity:
CAS# 59-23-4: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
Epidemiology: No information available.
Teratogenicity: Effects on Newborn: Germ cell effects, oral-rat TDLo=1000g/kg; Growth Statistics, oral-rat TDLo=440g/kg; Live birth index, oral-mouse TDLo=165g/kg. Embryo or fetus, oral-rat TDLo=240g/kg.
Reproductive Effects: Fertility: Abortion, oral-mouse TDLo=1260g/kg.
Neurotoxicity: No information available.
Mutagenicity: No information available.
Other Studies: No data available.

Section 12 - Ecological Information

No information available.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	IATA	RID/ADR	IMO	Canada TDG
Shipping Name:	No information available.				No information available.
Hazard Class:					
UN Number:					
Packing Group:					

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 59-23-4 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.
Section 12b
None of the chemicals are listed under TSCA Section 12b.
TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.
SARA

CERCLA Hazardous Substances and corresponding RQs
None of the chemicals in this material have an RQ.
SARA Section 302 Extremely Hazardous Substances
None of the chemicals in this product have a TPQ.
Section 313
No chemicals are reportable under Section 313.
Clean Air Act:
This material does not contain any hazardous air pollutants. This material does not contain any Class 1 Ozone depletors. This material does not contain any Class 2 Ozone depletors.
Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA. None of the chemicals in this product are listed as Priority Pollutants under the CWA. None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
OSHA:
None of the chemicals in this product are considered highly hazardous by OSHA.

STATE
CAS# 59-23-4 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives
Hazard Symbols:
Not available.
Risk Phrases:

Safety Phrases:
S 24/25 Avoid contact with skin and eyes.
S 37 Wear suitable gloves.
S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S 28A After contact with skin, wash immediately with plenty of water.

WGK (Water Danger/Protection)
CAS# 59-23-4: 0
Canada - DSL/NDSL
CAS# 59-23-4 is listed on Canada's DSL List.
Canada - WHMIS
This product has a WHMIS classification of D2A.
Canadian Ingredient Disclosure List
Exposure Limits

Section 16 - Additional Information

MSDS Creation Date: 7/14/1999
Revision #3 Date: 3/18/2003

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Material Safety Data Sheet
Gelatin (Granular)

ACC# 00663

Section 1 - Chemical Product and Company Identification

MSDS Name: Gelatin (Granular)
Catalog Numbers: AC410870000, AC410875000
Synonyms: Absorbable Gelatin Sponge; Gelatine; Pharmagel.
Company Identification:

Acros Organics N.V.
One Reagent Lane
Fair Lawn, NJ 07410

For information in North America, call: 800-ACROS-01
For emergencies in the US, call CHEMTREC: 800-424-9300

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
9000-70-8	GELATIN	ca 100	232-554-6

Hazard Symbols: None listed.
Risk Phrases: None listed.

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white to pale yellow solid. **Caution!** May cause eye and skin irritation. May cause respiratory tract irritation. May cause fetal effects based upon animal studies. This is expected to be a low hazard for usual industrial handling.
Target Organs: No data found.

Potential Health Effects

Eye: Dust may cause mechanical irritation.
Skin: Dust may cause mechanical irritation. Intraperitoneal injection has resulted in fetal effects.
Ingestion: Low hazard for usual industrial handling.
Inhalation: May cause respiratory tract irritation.
Chronic: Intraperitoneal injection has resulted in fetal effects.

Section 4 - First Aid Measures

Eyes: Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
Skin: Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.
Ingestion: If victim is conscious and alert, give 2-4 cupfuls of milk or water. Get medical aid.
Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Combustion generates toxic fumes.
Extinguishing Media: Use water spray, dry chemical, or carbon dioxide.
Flash Point: Not applicable.
Autoignition Temperature: Not applicable.
Explosion Limits, Lower: Not available.
Upper: Not available.
NFPA Rating: (estimated) Health: 1; Flammability: 0; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with skin and eyes. Avoid ingestion and inhalation.
Storage: Store in a cool, dry, well-ventilated area away from incompatible substances.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.

Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
GELATIN	none listed	none listed	none listed

OSHA Vacated PELs: GELATIN: No OSHA Vacated PELs are listed for this chemical.

Personal Protective Equipment

Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin: Wear appropriate protective gloves to prevent skin exposure.

Clothing: Wear appropriate protective clothing to minimize contact with skin.

Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

Section 9 - Physical and Chemical Properties

Physical State: Solid
Appearance: white to pale yellow
Odor: none reported
pH: 6.0 (6% solution)
Vapor Pressure: Negligible.
Vapor Density: Not available.
Evaporation Rate: Negligible.
Viscosity: Not available.
Boiling Point: Not applicable.
Freezing/Melting Point: Not available.
Decomposition Temperature: Not available.
Solubility: Soluble in water.
Specific Gravity/Density:0.68 (water=1)
Molecular Formula: Varies
Molecular Weight: Not available.

Section 10 - Stability and Reactivity

Chemical Stability: Stable under normal temperatures and pressures.
Conditions to Avoid: High temperatures, incompatible materials, dust generation.
Incompatibilities with Other Materials: Strong oxidizers.
Hazardous Decomposition Products: Carbon monoxide, oxides of nitrogen, carbon dioxide.
Hazardous Polymerization: Has not been reported.

Section 11 - Toxicological Information

RTECS#:
CAS# 9000-70-8: LX8580000
LD50/LC50:
Not available.

Carcinogenicity:
CAS# 9000-70-8: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
Epidemiology: No information available.
Teratogenicity: Effects on Newborn: Reduced weight gain, intraperitoneal mouse TDLo=700mg/kg. Specific Developmental Abnormalities: Urogenital; intraperitoneal mouse TDLo=700mg/kg.
Reproductive Effects: No information available.
Neurotoxicity: No information available.
Mutagenicity: Please refer to RTECS# LX8580000 for specific information.
Other Studies: See actual entry in RTECS for complete information.

Section 12 - Ecological Information

Ecotoxicity: No data available. No information available.
Environmental: No information reported.
Physical: No information available.
Other: None.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	IATA	RID/ADR	IMO	Canada TDG

Shipping Name:	No information available.	No information available.
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 9000-70-8 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.
Section 12b
None of the chemicals are listed under TSCA Section 12b.
TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.
SARA

CERCLA Hazardous Substances and corresponding RQs
None of the chemicals in this material have an RQ.
SARA Section 302 Extremely Hazardous Substances
None of the chemicals in this product have a TPQ.
Section 313
No chemicals are reportable under Section 313.
Clean Air Act:
This material does not contain any hazardous air pollutants. This material does not contain any Class 1 Ozone depletors. This material does not contain any Class 2 Ozone depletors.
Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA. None of the chemicals in this product are listed as Priority Pollutants under the CWA. None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
OSHA:
None of the chemicals in this product are considered highly hazardous by OSHA.
STATE
CAS# 9000-70-8 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives
Hazard Symbols:
Not available.
Risk Phrases:

Safety Phrases:

WGK (Water Danger/Protection)
CAS# 9000-70-8: 0
Canada - DSL/NDSL
CAS# 9000-70-8 is listed on Canada's DSL List.
Canada - WHMIS
WHMIS: Not available.
Canadian Ingredient Disclosure List
Exposure Limits

Section 16 - Additional Information

MSDS Creation Date: 9/02/1997
Revision #5 Date: 3/18/2003

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Material Safety Data Sheet
Hydroxylapatite

ACC# 08799

Section 1 - Chemical Product and Company Identification

MSDS Name: Hydroxylapatite
Catalog Numbers: AC371260000, AC371260250, AC371261000
Synonyms: Calcium phosphate hydroxide; Durapatite
Company Identification:

Acros Organics N.V.
One Reagent Lane
Fair Lawn, NJ 07410

For information in North America, call: 800-ACROS-01
For emergencies in the US, call CHEMTREC: 800-424-9300

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
1306-06-5	Hydroxylapatite		215-145-7

Hazard Symbols: None listed.
Risk Phrases: None listed.

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Not available. Appearance: white powder. Not available.
Target Organs: None known.

Potential Health Effects
Eye: May cause eye irritation.
Skin: May cause skin irritation. May be harmful if absorbed through the skin.
Ingestion: May cause irritation of the digestive tract.
Inhalation: May cause respiratory tract irritation. May be harmful if inhaled.
Chronic: Not available.

Section 4 - First Aid Measures

Eyes: Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
Skin: Get medical aid. Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes.
Ingestion: Get medical aid. Wash mouth out with water.
Inhalation: Remove from exposure and move to fresh air immediately.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear.
Extinguishing Media: Use water spray, dry chemical, carbon dioxide, or chemical foam.
Flash Point: Not available.
Autoignition Temperature: Not available.
Explosion Limits, Lower: Not available.
Upper: Not available.
NFPA Rating: Not published.

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container.

Section 7 - Handling and Storage

Handling: Avoid breathing dust, vapor, mist, or gas. Avoid contact with skin and eyes.
Storage: Store in a cool, dry place. Store in a tightly closed container.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs

Hydroxylapatite	none listed	none listed	none listed

OSHA Vacated PELs: Hydroxylapatite: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Not available.
Skin: Wear appropriate protective gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to prevent skin exposure.
Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

Section 9 - Physical and Chemical Properties

Physical State: Powder
Appearance: white
Odor: Not available.
pH: Not available.
Vapor Pressure: Not available.
Vapor Density: Not available.
Evaporation Rate: Not available.
Viscosity: Not available.
Boiling Point: Not available.
Freezing/Melting Point:1700 deg C
Decomposition Temperature: Not available.
Solubility: practically insoluble
Specific Gravity/Density: Not available.
Molecular Formula:HCa5O13P3
Molecular Weight:502.31

Section 10 - Stability and Reactivity

Chemical Stability: Not available.
Conditions to Avoid: Incompatible materials.
Incompatibilities with Other Materials: Strong oxidizing agents.
Hazardous Decomposition Products: Not available.
Hazardous Polymerization: Has not been reported

Section 11 - Toxicological Information

RTECS#:
CAS# 1306-06-5: MY8434000
LD50/LC50:

CAS# 1306-06-5:
Oral, mouse: LD50 = >99500 mg/kg;
Oral, rat: LD50 = >25350 mg/kg;
Carcinogenicity:
CAS# 1306-06-5: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
Epidemiology: No data available.
Teratogenicity: No data available.
Reproductive Effects: No data available.
Neurotoxicity: No data available.
Mutagenicity: No data available.
Other Studies: The toxicological properties have not been fully investigat ed.

Section 12 - Ecological Information

No information available.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	IATA	RID/ADR	IMO	Canada TDG
Shipping Name:	No information available.				No information available.
Hazard Class:					
UN Number:					
Packing Group:					

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 1306-06-5 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.
Section 12b
None of the chemicals are listed under TSCA Section 12b.
TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.
SARA

CERCLA Hazardous Substances and corresponding RQs
None of the chemicals in this material have an RQ.
SARA Section 302 Extremely Hazardous Substances
None of the chemicals in this product have a TPQ.
Section 313
No chemicals are reportable under Section 313.
Clean Air Act:
This material does not contain any hazardous air pollutants. This material does not contain any Class 1 Ozone depletors. This material does not contain any Class 2 Ozone depletors.
Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA. None of the chemicals in this product are listed as Priority Pollutants under the CWA. None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
OSHA:
None of the chemicals in this product are considered highly hazardous by OSHA.
STATE
CAS# 1306-06-5 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives
Hazard Symbols:
Not available.
Risk Phrases:

Safety Phrases:
S 24/25 Avoid contact with skin and eyes.

WGK (Water Danger/Protection)
CAS# 1306-06-5: 0
Canada - DSL/NDSL
CAS# 1306-06-5 is listed on Canada's DSL List.
Canada - WHMIS
WHMIS: Not available.
Canadian Ingredient Disclosure List
Exposure Limits

Section 16 - Additional Information

MSDS Creation Date: 6/10/2003
Revision #0 Date: Original.

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Material Safety Data Sheet
D-(+)-Maltose Monohydrate

ACC# 13585

Section 1 - Chemical Product and Company Identification

MSDS Name: D-(+)-Maltose Monohydrate
Catalog Numbers: S71965, S719651, BP684-500, M75-100
Synonyms: A disaccharide found in starch; 4-(alpha-D-glucosido)-D-glucose monohydrate.
Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
6363-53-7	D-(+)-Maltose monohydrate	90	unlisted
69-79-4	Maltose	-	200-716-5

Hazard Symbols: None listed.
Risk Phrases: None listed.

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: colorless solid. **Caution!** May cause eye and skin irritation. May cause respiratory tract irritation.
Target Organs: None.

Potential Health Effects
Eye: May cause eye irritation.
Skin: May cause skin irritation.

Ingestion: May cause irritation of the digestive tract.
Inhalation: May cause respiratory tract irritation.
Chronic: No information found.

Section 4 - First Aid Measures

Eyes: In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical aid.
Skin: In case of contact, flush skin with plenty of water. Remove contaminated clothing and shoes. Get medical aid if irritation develops and persists. Wash clothing before reuse.
Ingestion: If swallowed, do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical aid.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. This material in sufficient quantity and reduced particle size is capable of creating a dust explosion.
Extinguishing Media: Use extinguishing media most appropriate for the surrounding fire.
Flash Point: Not applicable.
Autoignition Temperature: Not applicable.
Explosion Limits, Lower: Not available.
Upper: Not available.
NFPA Rating: (estimated) Health: 1; Flammability: 1; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Avoid breathing dust.

Storage: Store in a tightly closed container. Store in a cool, dry, well-ventilated area away from incompatible substances.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.

Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
D-(+)-Maltose monohydrate	none listed	none listed	none listed
Maltose	none listed	none listed	none listed

OSHA Vacated PELs: D-(+)-Maltose monohydrate: No OSHA Vacated PELs are listed for this chemical. Maltose: No OSHA Vacated PELs are listed for this chemical.

Personal Protective Equipment

Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin: Glove protection is not normally required.

Clothing: Wear appropriate protective clothing to minimize contact with skin.

Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

Section 9 - Physical and Chemical Properties

Physical State: Solid
Appearance: colorless
Odor: none reported
pH: Not available.
Vapor Pressure: Not available.
Vapor Density: Not available.
Evaporation Rate: Not available.
Viscosity: Not available.
Boiling Point: Not available.
Freezing/Melting Point:266 deg F
Decomposition Temperature: Not available.
Solubility: 1080 g/l (20 C) in water.
Specific Gravity/Density:1.54 (water=1)
Molecular Formula:C12H22O11.H2O
Molecular Weight:360.29

Section 10 - Stability and Reactivity

Chemical Stability: Stable.
Conditions to Avoid: Dust generation, exposure to moist air or water.
Incompatibilities with Other Materials: Strong oxidizing agents.
Hazardous Decomposition Products: Carbon monoxide, carbon dioxide.
Hazardous Polymerization: Has not been reported.

Section 11 - Toxicological Information

RTECS#:
CAS# 6363-53-7 unlisted.
CAS# 69-79-4: OO5250000
LD50/LC50:
Not available.

CAS# 69-79-4:
Oral, mouse: LD50 = >44 gm/kg;
Oral, rat: LD50 = 34800 mg/kg;
Carcinogenicity:
CAS# 6363-53-7: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA. CAS# 69-79-4: Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
Epidemiology: No information available.
Teratogenicity: No information available.
Reproductive Effects: No information available.
Neurotoxicity: No information available.
Mutagenicity: No information available.
Other Studies: No data available.

Section 12 - Ecological Information

No information available.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	IATA	RID/ADR	IMO	Canada TDG
Shipping Name:	No information available.				No information available.
Hazard Class:					
UN Number:					
Packing Group:					

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 6363-53-7 is not on the TSCA Inventory because it is a hydrate. It is considered to be listed if the CAS number for the anhydrous form is on the inventory (40CFR720.3(u)(2)).
CAS# 69-79-4 is listed on the TSCA inventory.

Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.

Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.

Section 12b
None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.

SARA

CERCLA Hazardous Substances and corresponding RQs
None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances
None of the chemicals in this product have a TPQ.

Section 313
No chemicals are reportable under Section 313.

Clean Air Act:
This material does not contain any hazardous air pollutants. This material does not contain any Class 1 Ozone depletors. This material does not contain any Class 2 Ozone depletors.

Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA. None of the chemicals in this product are listed as Priority Pollutants under the CWA. None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:
None of the chemicals in this product are considered highly hazardous by OSHA.
STATE
CAS# 6363-53-7 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
CAS# 69-79-4 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives
Hazard Symbols:
Not available.
Risk Phrases:

Safety Phrases:
S 24/25 Avoid contact with skin and eyes.

WGK (Water Danger/Protection)
CAS# 6363-53-7: No information available.
CAS# 69-79-4: 0
Canada - DSL/NDSL
CAS# 69-79-4 is listed on Canada's DSL List.
Canada - WHMIS
This product has a WHMIS classification of Not controlled..
Canadian Ingredient Disclosure List
Exposure Limits

Section 16 - Additional Information

MSDS Creation Date: 7/14/1999
Revision #3 Date: 4/18/2002

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

MSDS GLOSSARY

The following glossary was provided by the Environmental Health and Safety Department at the University of Texas at Austin. Please visit their web site for additional MSDS information and resources:

http://www.utexas.edu/safety/ehs/msds/

ACGIH—*A*merican *C*onference of *G*overnmental *I*ndustrial *H*ygienists. An organization of professionals in governmental agencies or educational institutions engaged in occupational safety and health programs. ACGIH develops and publishes recommended occupational exposure limits for chemical substances and physical agents. See *TLV*.

Acid—A substance that produces hydrogen ions (H+) in aqueous solutions. An acid will destroy human tissue on contact. The pH values of acids are between 0 and 6. Strong acids have a lower pH and are more corrosive than weak acids. Examples of strong acids include hydrochloric acid, nitric acid, and phosphoric acid. *See also pH, Bases, Corrosive*.

Acute Effects—Adverse symptoms that occur immediately or shortly after an exposure to a chemical. Common symptoms of acute exposure include headache, dizziness, or nausea.

Acute Toxicity—Acute effects resulting from a single dose of, or exposure to, a substance.

Aerosol—A fine suspension in the air of small particles (*e.g.*, smoke or fog).

Air-Purifying Respirator—A respirator that uses chemicals to remove specific gases and vapors from the air or that uses a mechanical filter to remove particulate matter. An air-purifying respirator must only be used when there is sufficient oxygen to sustain life and the air contaminant level is below the concentration limits of the device. See also *Chemical Cartridge Respirator*.

Alkali—See *Base*.

Allergic Reaction—An abnormal response by the body to chemical or physical stimuli (*e.g.*, hives, sneezing).

Anesthetic—A chemical that causes a total or partial loss of sensation. Overexposure to anesthetics can cause impaired judgment, dizziness, drowsiness, headache, unconsciousness, and even death. Examples include alcohol, paint remover, and degreasers.

ANSI—*A*merican *N*ational *S*tandards *I*nstitute is a privately funded, voluntary membership organization that identifies industrial and public needs for national consensus standards and coordinates development of such standards.

Antidote—A remedy to relieve, prevent, or counteract the effects of a poison.

Appearance—A description of a substance at normal room temperature and normal atmospheric conditions. Appearance includes the color, size, and consistency of a material.

Aquatic Toxicity—The adverse effects to marine life that result from being exposed to a toxic substance.

Asphyxiant—A vapor or gas that can cause unconsciousness or death by suffocation due to lack of oxygen. Most simple asphyxiants are harmful to the body only when they become so concentrated that they reduce oxygen in the air to dangerous levels of 18 percent or lower. The normal level of oxygen in the air is about 21 percent. Asphyxiation is one of the principal potential hazards of working in confined and enclosed spaces.

Asymptomatic—Showing no symptoms.

Atm—*Atmosphere*, a unit of pressure equal to 760 mmHg (mercury) at sea level.

Auto-Ignition Temperature—The minimum temperature at which a substance can ignite without a spark or a flame. Some examples: acetone 538°C (1000°F), ethyl ether 180°C (356°F), phenol 715°C (1319°F).

Base—A substance that produces hydroxide ions (OH-) in aqueous solution. The pH values of bases are between 8 and 14. Strong bases have a higher pH and are more corrosive than weak bases. Examples of strong bases include sodium hydroxide, and ammonium hydroxide. See also *pH, Acid, Corrosive*.

Biodegradable—Capable of being broken down into non harmful products by the action of living things.

Boiling Points (BP)—The temperature at which a liquid changes to a vapor state at a given pressure. The boiling point is usually expressed in degrees Fahrenheit at sea level pressure (760 mmHg, or one atmosphere).

Some examples of boiling points:

Propane	-42°C (-44°F)
Butane	-0.5°C (31°F)
Gasoline	38°C (100°F)
Water	100°C (212°F)
Ethylene Glycol (Antifreeze)	197°C (387°F)

Bonding—The interconnecting of two objects by means of a clamp and bare wire. Its purpose is to equalize the electrical potential between the objects to prevent a static discharge when transferring a flammable liquid from one container to another. The conductive path is provided by clamps that make contact with the charged object and a low resistance flexible cable which allows the charge to equalize.

CAA—*C**lean Air Act*** was enacted to regulate/reduce air pollution. CAA is administered by the U.S. Environmental Protection Agency (EPA).

Carcinogen—A substance or agent that has been demonstrated to cause or produce cancer in mammals, including humans. Carcinogens are regulated by OSHA and are listed in the National Toxicology Program Annual Report of Carcinogens.

CAS—*Chemical Abstracts Service* is an organization under the American Chemical Society. CAS abstracts and indexes chemical literature from all over the world in *Chemical Abstracts*. *CAS Numbers* are used to identify specific chemicals or mixtures.

Caustic—See *Base*.

cc—*Cubic centimeter* is a volume measurement in the metric system that is equal in capacity to one milliliter (ml). One quart is about 946 cubic centimeters (0.946L).

Ceiling Limit (PEL or TLV)—The maximum allowable human exposure limit for an airborne substance which is not to be exceeded even momentarily. See also *PEL* and *TLV*.

Centigrade—A unit of temperature. To convert from centigrade to Fahrenheit, multiply the temperature given in centigrade degrees by 9, divide that number by 5, then add 32.

Central Nervous System—The brain and spinal cord. These organs supervise and coordinate the activity of the entire nervous system.

CERCLA—*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*. The Act requires that the Coast Guard National Response Center be notified in the event of a hazardous substance release. The Act also provides for a fund (the Superfund) to be used for the cleanup of abandoned hazardous waste disposal sites.

CFR—*Code of Federal Regulations* is a collection of the regulations that have been promulgated under United States Law.

Chemical Cartridge Respirator—A respirator that uses various chemical substances to purify inhaled air of certain gases and vapors. This type respirator is effective for concentrations ten times or more times (depending on the type of respirator) the TLV of the contaminant, if the contaminant has warning properties (odor or irritation) below the TLV. See also *Air-Purifying Respirator*.

Chemical Family—A group of single elements or compounds with a common general name. Example: acetone, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) are of the "Ketone" family; acrolein, furfural, and acetaldehyde are of the "aldehyde" family.

Chemical Pneumonitis—Inflammation of the lungs caused by accumulation of fluids due to chemical irritation.

CHEMTREC—*Chemical Transportation Emergency Center* is a national center established by the Chemical Manufacturers Association (CMA) to relay pertinent emergency information concerning specific chemicals on requests from individuals. CHEMTREC has a 24-hour toll-free telephone number (800-424-9300) to help respond to chemical transportation emergencies.

Chronic Effect—Adverse symptoms of chemical exposure that develop slowly over a long period of time (weeks, months or years) due to repeated long-term exposure to a substance. Examples include cancer or damage to certain internal organs. Also see *Acute Effect*.

Chronic Exposure—Repeated long-term contact with a substance.

Chronic Toxicity—Adverse effects resulting from repeated doses of or exposures to a substance over a long period of time.

Clean Air Act—Clean Air Act (CAA) was enacted to regulate/reduce air pollution. CAA is administered by the U.S. Environmental Protection Agency.

Clean Water Act—Clean Water Act (CWA) Federal law enacted to regulate/reduce water pollution. CWA is administered by the U.S. Environmental Protection Agency.

Combustible—For liquids, a liquid with a flash point above 100°F (37.8°C) but below 200°F (93.3°C). Non-liquid substances such as wood and paper are classified as "ordinary combustibles" by NFPA. Also see *Flammable Liquid*.

Common Name—A name used to identify a chemical other than its chemical name (*e.g.*, code name, code number, trade name, brand name, or generic name). See *Generic*.

Compressed Gas—

a. A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 pounds per square inch (psi) at 70°F (21.1°C); or

b. A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C); or

c. A liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-323-72.

Conc—Concentration.

Concentration—The relative amount of a substance when combined or mixed with other substances. Examples: 2 ppm hydrogen sulfide in air, or a 50 percent caustic solution.

Conditions to Avoid—Conditions encountered during handling or storage that could cause a substance to become unstable.

Corrosive Material—Any solid, liquid, or gas that burns, irritates, or destroys organic tissues such as the skin, lungs, and stomach. Corrosives can also destroy metal and other building materials. The term corrosive includes both acids and bases.

CWA—*Clean Water Act* was enacted to regulate/reduce water pollution. It is administered by the Environmental Protection Agency (EPA).

Decomposition—Breakdown of a material or substance by heat, chemical reaction, electrolysis, decay, or other processes into parts, elements, or simpler compounds.

Density—The mass (weight) per unit volume of a substance. Usually given in pounds per gallon or grams per milliliter. See also *Specific Gravity*.

Depressant—A substance that reduces a bodily functional activity or an instinctive desire, such as appetite.

Dermal—Relating to skin.

Dermal Toxicity—Adverse effects resulting from skin exposure to a substance.

Dike—A barrier constructed to control or confine hazardous substances and prevent them from entering sewers, ditches, streams, or other flowing waters.

DOT—U.S. Department of Transportation regulates transportation of chemicals and other substances.

Dry Chemical—A powdered fire-extinguishing agent usually composed of sodium bicarbonate, potassium bicarbonate, *etc*.

Environmental Toxicity—Information obtained as a result of conducting environmental testing designed to study the effects on aquatic and plant life.

EPA—*U.S. **E**nvironmental **P**rotection **A**gency*.

Evaporation Rate—The rate at which a material will vaporize (evaporate) when compared to the known rate of vaporization of a standard material. The evaporation rate can be useful in evaluating the health and fire hazards of a material. The designated standard material is usually normal butyl acetate (NBUAC or n-BuAc), with a vaporization rate designated as 1.0. Vaporization rates of other solvents or materials are then classified as:

- FAST evaporating if greater than 3.0. Examples:
  - Methyl Ethyl Ketone = 3.8
  - Acetone = 5.6
  - Hexane = 8.3
- MEDIUM evaporating if 0.8 to 3.0. Examples:
  - 190 proof (95%) Ethyl Alcohol = 1.4
  - VM&P Naphtha = 1.4
  - MIBK = 1.6
- SLOW evaporating if less than 0.8. Examples:
  - Xylene = 0.6
  - Isobutyl Alcohol = 0.6
  - Normal Butyl Alcohol = 0.4
  - Water = 0.3
  - Mineral Spirits = 0.1

Explosive—A chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.

Exposure or **Exposed—**Exposure to a chemical occurs when the chemical is taken into the body through inhalation, ingestion, skin absorption, or any other means.

Exposure Limits—The concentration in workplace air of a chemical deemed the maximum acceptable. This means that most workers can be exposed at given levels or lower without harmful effects.

Exposure limits in common use are:

- TLV-TWA: Threshold limit value—time-weighted average.
- STEL: Short-term exposure limit.
- C: Ceiling value.

Extinguishing Media—The fire-fighting substance to be used to control a material in the event of a fire. It is usually identified by its generic name, such as fog, foam, water, *etc*.

Eye Protection—Recommended safety glasses, chemical splash goggles, or face shields to be used when handling a hazardous material.

F Fahrenheit—is a scale for measuring temperature. On the Fahrenheit scale, water boils at 212°F and freezes at 32°F. To convert a temperature from degrees Fahrenheit to degrees Centigrade, subtract 32 from the temperature, multiply that number by five, then divide by 9.

FDA—*U.S.* ***F****ood and* ***D****rug* ***A****dministration*.

Fetus—The developing young in the uterus from the seventh week of gestation until birth.

FIFRA—*F**ederal*** ***I****nsecticide,* ***F****ungicide, and* ***R****odenticide* ***A****ct* requires that certain useful poisons, such as chemical pesticides, sold to the public contain labels that carry health hazard warnings to protect users. It is administered by EPA.

First Aid—Emergency measures to be taken when a person is suffering from overexposure to a hazardous material, before regular medical help can be obtained.

Flammable—A chemical that falls into one of the following four categories:

- Liquid—A liquid with a flashpoint below 100°F (37.8°C).
- Solid—A solid, other than a blasting agent or explosive, that is able to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a hazard.
- Gas—A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less.
- Aerosol—A chemical substance or mixture dispensed from its container as a spray or mist by a propellant under pressure that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback at any degree of valve opening.

Flammability Range—The lower and upper concentrations of a chemical vapor in air that will ignite if an ignition source is present. The lower concentration range is called the lower explosive limit (LEL), and the upper concentration range is called the upper explosive limit (UEL).

Some examples of the LEL and UEL for some common chemicals:

acetylene	2.5-80%
acetone	2.6-12.8%
propane	2.4-9.5%
toluene	1.27-7%
diesel fuel	1-5%

Flashback—A flashback occurs when flame from a torch burns back into the tip, the torch, or the hose. It is often accompanied by a hissing or squealing sound with a smoky or sharp-pointed flame.

Flashpoint—The minimum temperature at which a liquid gives off vapor in sufficient concentration to ignite. Used to determine how flammable a liquid is.

Foreseeable Emergency—Any potential occurrence such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment which could result in an uncontrolled release of a hazardous chemical into the workplace.

Formula—The scientific expression of the chemical composition of a material (*e.g.*, water is H2O, sulfuric acid is H2SO4, sulfur dioxide is SO2).

Fume—The particulate, smoke-like emanation from the surface of heated metals.

g—*Gram* is a metric unit of weight. One U.S. ounce is about 28.4 grams.

General Exhaust—A system for exhausting air containing contaminants from a general work area. Also see *Local Exhaust.*

Generic Name—A designation or identification used to identify a chemical by other than its chemical name (*e.g.*, code name, code number, trade name, brand name).

Gestation—The development of the fetus in the uterus from conception to birth; pregnancy.

g/kg—Grams per kilogram is an expression of dose used in oral and dermal toxicology testing to denote grams of a substance dosed per kilogram of animal body weight. Also see *kg*.

Grounding—The procedure used to carry an electrical charge to ground through a conductive path. A typical ground may be connected directly to a conductive water pipe or to a grounding bus and ground rod. See *Bonding.*

Hand Protection—Specific type of gloves or other hand protection required to prevent harmful exposure to hazardous materials.

Hazardous Chemical—Any chemical whose presence or use is a physical hazard or health hazard.

Hazardous Warning—Words, pictures, or symbols, presented on a label to inform of the dangers of a chemical.

HCS—Hazard Communication Standard is an OSHA regulation issued under 29 CFR Part 1910.1200. Also known as HazCom or Right-to-Know.

Health Hazard—A chemical for which there is significant evidence, based on at least one study conducted in accordance with established scientific principles, that acute or chronic health effects may occur in exposed employees. The term *health hazard* includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes, or mucous membranes.

Highly Toxic—A chemical in any of the following three categories:

- A chemical with a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each. (ORL-RAT LD50)
- A chemical with a median lethal dose (LD50) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each. (SKN-RBT LD50)
- A chemical that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each. (IHL-RAT LC50)

Hormones—Act as chemical messengers to body organs.

IARC—*I*nternational *A*gency for *R*esearch on *C*ancer.

Ignitable—Capable of being set on fire.

Impervious—A material that does not allow another substance to pass through or penetrate it.

Incompatible—Materials that could cause dangerous reactions by direct contact with one another. Reactions between incompatible chemicals can cause an explosion, a fire, or the release of a toxic gas.

Ingestion—Taking in by the mouth.

Inhalation—Breathing in of a substance in the form of a gas, vapor, fume, mist, or dust.

Inhibitor—A chemical added to another substance to prevent an unwanted chemical change.

Insol—See *Insoluble*.

Insoluble—Not capable of being dissolved in a liquid.

Irritant—A chemical, which is not corrosive, that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact.

kg—Kilogram is a metric unit of weight. One kilogram is about 2.2 U.S. pounds. Also see *g/kg*, *g*, and *mg*.

L—Liter is a metric unit of capacity. A U.S. quart is about 9/10 of a liter.

Lacrimation—Secretion and discharge of tears.

Label—Notice attached to a container, bearing information concerning its contents.

LC—Lethal concentration is the concentration of a substance being tested that will kill.

LCL—Lethal concentration, low, lowest concentration of a gas or vapor capable of killing a specified species over a specified time.

LC50—The concentration of a material in air that will kill 50 percent of a group of test animals with a single exposure (usually 1 to 4 hours). The LC50 is expressed as parts of material per million parts of air, by volume (ppm) for gases and vapors, or as micrograms of material per liter of air (µg/l) or milligrams of material per cubic meter of air (mg/m3) for dusts and mists, as well as for gases and vapors. See also *Highly Toxic* and *Toxic*.

LD—Lethal dose is the quantity of a substance being tested that will kill.

LDL—Lethal dose low, lowest administered dose of a material capable of killing a specified test species.

LD50—A single dose of a material expected to kill 50 percent of a group of test animals. The LD50 dose is usually expressed as milligrams or grams of material per kilogram of animal body weight (mg/kg or g/kg). The material may be administered by mouth or applied to the skin. See also *Highly Toxic* and *Toxic*.

LEL, or **LFL—**Lower explosive limit, or lower flammable limit, of a vapor or gas; the lowest concentration (lowest percentage of the substance in air) that will produce a flash of fire when an ignition source is present. At concentrations lower than the LEL, the mixture is too *lean* to burn. Also see *UEL* and *Flammability Range*.

Lethal Concentration—See LC50.

Lethal Dose—See *LD50*.

Local Exhaust—A system for capturing and exhausting contaminants from the air at the point where the contaminants are produced (welding, grinding, sanding, or other processes or operations). Also see *General Exhaust*.

m—Meter is a unit of length in the metric system. One meter is about 39 inches.

m3—Cubic meter is a metric measure of volume, approximately 35.3 cubic feet or 1.3 cubic yards.

Malaise—A feeling of general discomfort, distress, or uneasiness, an out-of-sorts feeling.

Mechanical Exhaust—A powered device, such as a motor-driven fan or air steam venturi tube, for exhausting contaminants from a workplace, vessel, or enclosure.

Mechanical Filter Respirator—A respirator used to protect against airborne particulate matter like dusts, mists, metal fume, and smoke. Mechanical filter respirators do not provide protection against gases, vapors, or oxygen deficient atmospheres.

Melting Point—The temperature at which a solid substance changes to a liquid state.

Metabolism—Physical and chemical processes taking place among the ions, atoms, and molecules of the body.

Meter—A unit of length, equivalent to 39.37 inches.

mg—Milligram is a metric unit of weight that is one-thousandth of a gram, i.e. 1000 milligrams equals one gram.

mg/kg—Milligrams of substance per kilogram of body weight is an expression of toxicological dose.

mg/m3—Milligrams per cubic meter is a unit for expressing concentrations of dusts, gases, or mists in air.

Micron (Micrometer)—A unit of length equal to one-millionth of a meter; approximately 0.000039 of an inch.

Mist—Suspended liquid droplets generated by condensation from the gaseous to the liquid state, or by breaking up a liquid into a dispersed state, such as splashing, foaming, or atomizing. Mist is formed when a finely divided liquid is suspended in air.

Mixture—Any combination of two or more chemicals.

ml—Milliliter is a metric unit of capacity, equal in volume to 1 cubic centimeter (cc), or approximately one-sixteenth of a cubic inch. One-thousandth of a liter.

mmHg—Millimeters (mm) of mercury (Hg) is a unit of measurement for low pressures or partial vacuums.

Molecular Weight—Weight (mass) of a molecule based on the sum of the atomic weights of the atoms that make up the molecule.

MSDS—*M*aterial *S*afety *D*ata *S*heet, a document containing information and instructions on the chemical and physical characteristics of a substance, its hazards and risks, safe handling requirements and the actions to be taken in the event of fire, spill or exposure.

Mutagen—A substance or agent capable of altering the genetic material in a living cell. See also *Reproductive Toxin*.

MW—See *Molecular Weight.*

Narcosis—A state of stupor, unconsciousness, or arrested activity produced by the influence of narcotics or other chemicals.

Nausea—Tendency to vomit, feeling of sickness at the stomach.

NFPA—*National Fire Protection Association* is an international membership organization which promotes and improves fire protection and prevention and establishes safeguards against loss of life and property by fire. Best known on the industrial scene for the National Fire Codes—16 volumes of codes, standards, recommended practices and manuals developed and periodically updated by NFPA technical committees. Among these is NFPA 704M, the code for showing hazards of materials as they might be encountered under fire or related emergency conditions, using the familiar diamond-shaped label or placard with appropriate numbers or symbols.

Neurotoxin—A material that affects the nerve cells and may produce emotional or behavioral abnormalities.

Neutralize—In acid-base chemistry, the process of bringing the pH to between 5 and 8, either by adding an acid to a base or by adding a base to an acid.

NIOSH—*National Institute for Occupational Safety and Health,* U.S. Public Health Service, U.S. Department of Health and Human Services (DHHS), among other activities, tests and certifies respiratory protective devices and air sampling detector tubes, recommends occupational exposure limits for various substances, and assists OSHA and MSHA in occupational safety and health investigations and research.

Nonflammable—Not easily ignited, or if ignited, not burning rapidly.

Non-Sparking Tools—Tools made from beryllium-copper or aluminum-bronze that greatly reduce the possibility of igniting dusts, gases, or flammable vapors. Although these tools may emit some sparks when striking metal, the sparks have a low heat content and are not likely to ignite most flammable liquids.

NTP—*National Toxicology Program* publishes an Annual Report on Carcinogens.

Odor—A description of the smell of the substance.

Odor Threshold—The lowest concentration of a substance's vapor, in air, that can be smelled.

Olfactory—Relating to the sense of smell.

Oral—Used in or taken into the body through the mouth.

Oral Toxicity—Adverse effects resulting from taking a substance into the body by mouth.

Organic Peroxide—An organic compound that is an oxidizer and contains the bivalent -O-O- structure and may be considered a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical.

OSHA—*O*ccupational *S*afety and *H*ealth *A*dministration, U.S. Department of Labor.

Overexposure—Exposure to a hazardous material beyond the allowable exposure limits.

Oxidizer—A substance that readily yields oxygen to or accepts electrons from another substance. By yielding oxygen or accepting electrons, an oxidizer can easily cause or enhance the combustion of other materials. Examples of oxidizers include bleach, which contains sodium hypochlorite, concentrated hydrogen peroxide (greater than 30%), and ammonium nitrate.

Pathologic—Pertaining to or caused by disease.

Pathology—Scientific study of alterations produced by disease.

PEL—*P*ermissible *E*xposure *L*imit is an occupational exposure limit established by OSHA's regulatory authority. It may be a time-weighted average (TWA) limit or a maximum concentration exposure limit.

Percent Volatile—Percent volatile by volume is the percentage of a liquid or solid (by volume) that will evaporate at a temperature of 70°F. Examples: butane, gasoline, and paint thinner (mineral spirits) are 100 percent volatile; their individual evaporation rates vary, but in time, each will evaporate completely.

pH—The symbol relating the hydrogen ion (H+) concentration to that of a given standard solution. A pH of 7 is neutral. Numbers increasing from 7 to 14 indicate greater alkalinity. Numbers decreasing from 7 to 0 indicate greater acidity.

Physical Hazard—Used to describe a chemical that is explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable, or water reactive.

Placenta—A structure attached to the wall of the uterus to nourish the fetus during pregnancy.

Polymerization—A chemical reaction in which one or more small molecules combine to form larger molecules. A hazardous polymerization is such a reaction that takes place at a rate that releases large amounts of energy. If hazardous polymerization can occur with a given material, the MSDS usually will list conditions that could start the reaction and, if the material contains a polymerization inhibitor, the length of time during which the inhibitor will be effective.

ppb—*P*arts *p*er *b*illion. The concentration of a particular chemical in solution. For every one part of the chemical. there are a billion parts of solution. Used to express very low concentrations.

ppm—*P*arts *p*er *m*illion. The concentration of a particular chemical in solution. For every one part of the chemical, there are a million parts of solution. Used to express very low concentrations. One inch in sixteen miles is a common example of the magnitude of parts per million.

Prenatal—Preceding birth.

psi—Pounds per square inch is the pressure a material exerts on the walls of a confining vessel or enclosure. For technical accuracy, pressure must be expressed as psig (pounds per square inch gauge) or psia (pounds per square inch absolute; that is, gauge pressure plus sea level atmospheric pressure, or psig plus approximately 14.7 pounds per square inch). See also *mmHg*.

Pulmonary—Relating to, or associated with, the lungs.

Pulmonary Edema—Fluid in the lungs.

Pyrophoric—A chemical substance that will ignite spontaneously in air at or below a temperature of 130°F (54.4°C).

Reaction—A chemical transformation or change. The interaction of two or more substances to form new substances.

Reactivity—Chemical reaction with the release of energy. Undesirable effects—such as pressure buildup, temperature increase, formation of noxious, toxic or corrosive byproducts—may occur because of the reactivity of a substance to heating, burning, direct contact with other materials, or other conditions in use or in storage.

RCRA—*R*esource *C*onservation and *R*ecovery *A*ct is environmental legislation aimed at controlling the generation, treatment, storage, transportation and disposal of hazardous wastes. It is administered by EPA.

Reducing Agent—In a reduction reaction, which always occurs simultaneously with an oxidation reaction, the reducing agent is the chemical or substance which combines with oxygen, or loses electrons to the reaction. See *Oxidation*.

REL—*R*ecommended *E*xposure *L*imit. The NIOSH REL is the highest allowable airborne concentration which is not expected to injure workers. It may be expressed as a ceiling limit or as a time-weighted average (TWA).

Reproductive Toxin—Substances that affect either male or female reproductive systems and may impair the ability to have children. See also *Mutagen.*

Respiratory Protection—Devices that will protect the wearer's respiratory system from overexposure by inhalation to airborne contaminants. Respiratory protection is used when a worker must work in an area where he/she might be exposed to concentration in excess of the allowable exposure limit.

Respiratory System—The breathing system that includes the lungs and the air passages (trachea or "windpipe," larynx, mouth, and nose) to the air outside the body, plus the associated nervous and circulatory supply.

Routes of Entry—The means by which material may gain access to the body, for example, inhalation, ingestion, and skin contact.

Self-Contained Breathing Apparatus—A respiratory protection device that consists of a supply or a means of respirable air, oxygen, or oxygen-generating material which is carried by the wearer.

Sensitizer—A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical.

Silicosis—A disease of the lungs (fibrosis) caused by the inhalation of silica dust.

Skn—Skin.

Skin—A notation sometimes used with PEL or TLV exposure data that indicates that the stated substance may be absorbed by the skin, mucous membranes, and eyes, either by airborne or by direct contact.

Skin Absorption—Ability of some hazardous chemicals to pass directly through the skin and enter the bloodstream.

Skin Toxicity—See *Dermal Toxicity*.

Solubility in Water—A term expressing the percentage of a material (by weight) that will dissolve in water at ambient temperature.

Solvent—A substance, usually a liquid, in which other substances are dissolved. The most common solvent is water.

Specific Chemical Identity—The chemical name, Chemical Abstracts Service (CAS) Registry Number, or any precise chemical designation of a substance.

Specific Gravity—The weight of a material compared to the weight of an equal volume of water is an expression of the density (or heaviness) of a material. Insoluble materials with specific gravity of less than 1.0 will float on water. Insoluble materials with specific gravity greater than 1.0 will sink in water. Some flammable liquids have specific gravities greater than 1.0 and will sink in water. Most flammable liquids have specific gravities less than 1.0 and, if not soluble, will float on water, which is an important consideration for fire suppression.

Spill or Leak Procedures—The methods, equipment, and precautions that should be used to control or clean up a leak or spill.

Splash-Proof Goggles—Eye protection that fits snugly against the face, and may have indirect ventilation ports.

Spontaneously Combustible—Capable of catching fire without an ignition source. Can occur due to oxidation in air or by internal heat buildup.

Stability—The ability of a material to remain unchanged. For MSDS purposes, a material is stable if it remains in the same form under expected and reasonable conditions of storage or use. Conditions that may cause instability (dangerous change) are stated; for example, temperatures above 150°F; shock from dropping.

STEL—*S*hort-*T*erm *E*xposure *L*imit (ACGIH terminology). See *TLV*.

Subcutaneous—Beneath the layers of the skin.

Supplied-Air Respirators—Air line respirators or self-contained breathing apparatus.

Sys—System or systemic.

Systemic Poison—A poison that spreads throughout the body, affecting all body systems and organs. Its adverse effect is not localized in one spot or area.

Systemic Toxicity—Adverse effects caused by a substance that affects the body in a general rather than local manner.

Synonym—Another name or names by which a material is known. Methyl alcohol, for example, is also known as methanol or wood alcohol.

Target Organ Toxin—A toxic substance that attacks a specific organ of the body. For example, overexposure to carbon tetrachloride can cause liver damage.

TCL—Toxic concentration low, the lowest concentration of a gas or vapor capable of producing a defined toxic effect in a specified test species over a specified time.

TDL—Toxic dose low, lowest administered dose of a material capable of producing a defined toxic effect in a specified test species.

Temp—Temperature.

Ter—See *Teratogen*.

Teratogen—A substance or agent, exposure to which by a pregnant female can result in malformations in the fetus.

Tfx—Toxic effects(s).

TLV—*Threshold Limit Value* is a term used by ACGIH to express the airborne concentration of material to which nearly all persons can be exposed day after day without adverse effects. ACGIH expresses TLVs in three ways:

- TLV-TWA: The allowable ***Time-Weighted Average*** concentration for a normal 8-hour workday or 40-hour workweek.
- TLV-STEL: The ***Short-Term Exposure Limit***, or maximum concentration for a continuous 15-minute exposure period (maximum of four such periods per day, with at least 60 minutes between exposure periods, and provided the daily TLV-TWA is not exceeded).
- TLV-C: The *Ceiling* exposure limit. The concentration that should not be exceeded even instantaneously.

Torr—A unit of pressure, equal to 1/760 atmosphere.

Toxic—A chemical falling within any of the following three categories:

- A chemical that has a median lethal dose (LD50) of more than 50 milligrams per kilogram but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

- A chemical that has a median lethal dose (LD50) of more than 200 milligrams per kilogram but not more than 1,000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.
- A chemical that has a median lethal concentration (LC50) in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than two milligrams per liter but not more than 20 milligrams per liter of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each. See also *Highly Toxic*.

Toxic Substance—Any substance that can cause acute or chronic injury to the human body, or which is suspected of being able to cause diseases or injury under some conditions.

Toxicity—The degree of poisoning that can occur from exposure to a chemical.

Trade name—The trademark name or commercial trade name for a material or product.

Transplacental—A chemical that is capable of causing physical defects in the developing embryo because it can easily cross the placental barrier between mother and fetus.

TSCA—*Toxic **S**ubstances **C**ontrol **A**ct*. Federal Environmental Legislation administered by EPA that regulates the manufacture, handling, and use of materials classified as "toxic substances."

TWA—*Time-**W**eighted **A**verage* exposure is the airborne concentration of a material to which a person is exposed, averaged over the total exposure time-generally the total workday (8 hours). Also see *TLV*.

UEL, or **UFL—*U**pper **e**xplosive **l**imit* or ***u**pper **f**lammable **l**imit* of a vapor or gas; the highest concentration (highest percentage of the substance in air) that will produce a flash of fire when an ignition source (heat, arc, or flame) is present. At higher concentrations, the mixture is too *rich* to burn. See also *LEL*.

ug—*Microgram*, one millionth of a gram.

Unstable—Tending toward decomposition or other unwanted chemical change during normal handling or storage.

Unstable Reactive—A chemical that, in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or become self-reactive under conditions of shock, pressure, or temperature.

Vapor—The gaseous form of a solid or liquid substance as it evaporates.

Vapor Density—The weight of a vapor or gas compared to the weight of an equal volume of air is an expression of the density of the vapor or gas. Materials lighter than air have vapor densities less than 1.0. Some examples are acetylene, methane,

hydrogen. Materials heavier than air, such as propane, hydrogen sulfide, ethane, butane, chlorine, and sulfur dioxide, have vapor densities greater than 1.0. All vapors and gases will mix with air, but the lighter materials will tend to rise and dissipate unless confined. Heavier vapors and gases are likely to concentrate in low places-along or under floors, in sumps, sewers, and manholes, in trenches and ditches where they may create fire or health hazards.

Vapor Pressure—The pressure exerted by a saturated vapor above its own liquid in a closed container. Vapor pressures reported on MSDS are in milliliters of mercury (mmHg) at 68°F (20°C), unless stated otherwise. Some important facts to remember are that vapor pressure increases with temperature, and the lower the boiling point of a chemical, the higher its vapor pressure.

Examples of vapor pressures at 20°C in mm Hg:

Acetone	184
Mercury	0.002
Methylene Chloride	350
Phenol	0.36

Ventilation—See *General Exhaust*, *Local Exhaust*, and *Mechanical Exhaust*.

Vermiculite—Substance used as sorbent for spill control and cleanup.

Viscosity—The tendency of a fluid to resist internal flow without regard to its density.

Volatility—A measure of how quickly a substance forms a vapor at ordinary temperatures. Chemicals with higher vapor pressures and lower boiling points will have higher volatilities and will evaporate quicker.

Water-Reactive—A chemical that reacts with water to release a gas that is either flammable or toxic.

Biosensors

Biosensors can be classified as structures or devices that specifically monitor the presence or concentration of a desired biological component. Examples of such biosensors include devices that detect the concentration of glucose in the blood and microfabricated arrays of nano-detectors capable of rapidly analyzing complex solutions for the presence of many analytes such as toxins and drug metabolites.

In this lab, we will concentrate on the history and science of glucose monitoring.

Before arriving to lab, please read the following paper for a good review of biosensors:

http://www.engr.utexas.edu/bme/ugrad/UGLab/resources/Biosensors.pdf

SECTION CONTENTS

INTRODUCTION TO BIOSENSORS

An essential component of a molecular sensor is the *reagent layer*(*s*). Creation of these layers requires the immobilization of recognition elements for the detection method. In the case of biosensors, these recognition elements are typically biomolecules such as enzymes, antibodies, and whole cells. These reagent layers are usually constructed from various polymers which can be easily deposited, and whose properties can be tailored according to hydrophilicity, hydrophobicity and mechanical requirements, while still allowing the covalent attachment of biorecognition ligands or the incorporation of whole cells.

In the following sections we will examine platinum electrodes biosensors and coulometric biosensors.

Platinum Electrode Biosensors

It is generally agreed that biosensor history started in 1962, and that the progenitor of the biosensor was the American scientist, Leland C. Clark. Clark had studied the electrochemistry of oxygen gas reduction at platinum (Pt) metal electrodes and pioneered the use of this chemical reaction as an oxygen- (and therefore *chemi*-) sensor. Platinum electrodes used as electrochemical oxygen detectors are often referred to generically as *Clark electrodes*.

Clark Electrodes

Clark had the ingenious idea of placing an enzyme that reacted with oxygen very close to the surface of the platinum electrode by trapping it physically against the electrode with a piece of dialysis membrane. He reasoned that he could follow the activity of the enzyme by following the changes in the oxygen concentration around it—thus, a *chemosensor* became a *biosensor*. The enzyme Clark chose was *glucose oxidase*, usually abbreviated as *GOD*.

GOD catalyses several reactions (Figure 2-1 illustrates these reactions). First, glucose reacts with the oxidized form of the enzyme to form gluconic acid, but leaves behind two electrons and two protons, thus reducing GOD. Next, oxygen dissolved in the surrounding fluid reacts with GOD, accepting the aforementioned electrons and protons to form H_2O_2 (hydrogen peroxide) and regenerating oxidized GOD—which is ready to react once more with glucose.

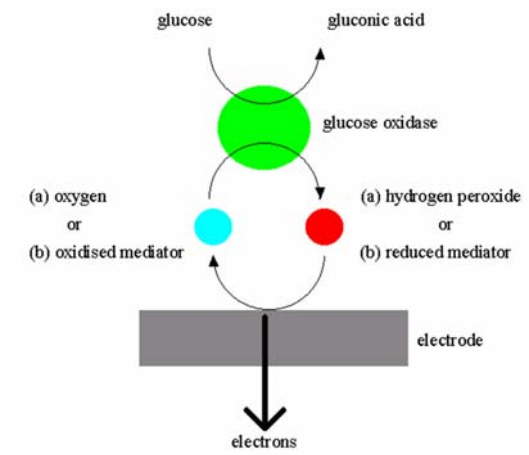

Figure 2-1. *Reactions caused by GOD at the Clark Electrode*

In Clark's experiments, the more glucose was present, the more oxygen was consumed and the less oxygen Clark could detect with his electrode. Another alternative was to detect (at that same platinum electrode but at a different voltage) the production of hydrogen peroxide rather than the consumption of oxygen. This system turns out to be more reliable because the sensor is less sensitive to varying background oxygen concentrations in the sample. Either way, thanks to the unique properties of the GOD enzyme and the platinum electrode, glucose concentration could be directly related to the output of Clark's potentiostat.

Commercial Biosensors

The first step toward commercial exploitation was taken in the 1970s by the Yellow Springs Instrument Company (YSI). In close collaboration with Clark, the YSI developed a series of laboratory-scale glucose sensors. Much work was invested in finding suitable membranes that rendered the GOD-platinum electrode technique reproducible and accurate.

YSI's success can be judged firstly by the fact that their sensors are used routinely in laboratory, near-point-of-care and even point-of-care situations in many clinics and hospitals, and secondly by the fact that many research groups working on other types of glucose sensors use YSI readings as their reference method.

The YSI Model Of Glucose Sensor

Figure 2-2 provides an example of the commercial YSI glucose sensor.

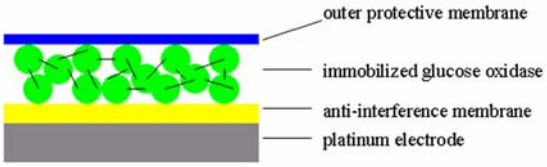

Figure 2-2. *YSI model of the GOD-platinum electrode technique*

An inner membrane of cellulose acetate is directly placed on the electrode to exclude certain interferents, such as ascorbic acid, while still allowing the free passage (and thus detection) of hydrogen peroxide. GOD is immobilized by chemical cross-linking —the enzyme remains active but the stability is increased. Finally, an outer membrane protects the sensing layers from fouling by proteins in the blood (often a problem in a system where the electrode is reused many times) and also extends the sensor's linear range of glucose measurement by slightly restricting the diffusion of glucose. The YSI machines also used automated sampling of whole, anticoagulated blood that is diluted with a standard buffer.

Home Care Glucose Sensors

The final challenge for glucose sensors was the mass market of home-care testing for Type I (insulin-dependant) diabetics. Glucose home-testing had been firmly in place for a decade—thanks again to GOD and its production of H_2O_2—but was based on the chemical reactions which produce a color change on a dry strip or in a solution. This color change would be compared by eye to a reference chart or (in more recent kits) read more accurately and automatically by a reflectometer.

The key research that lead to the next generation of home-test glucose sensors was performed in the early 1980's by H.A.O. Hill and I.J. Higgins and their respective colleagues at the University of Oxford and the Cranfield Institute of Technology. Their novel idea was to replace oxygen with a synthetic molecule—referred to as a *mediator*.

The Mediated Model of Glucose Sensor

In the mediated model of glucose senors (see Figure 2-3), instead of oxygen reacting with reduced GOD, it is an oxidized form of the *mediator* that does so. Thus, reduced mediator is formed instead of hydrogen peroxide. The reduced mediator is then reoxidised at the electrode, giving a current signal and regenerating the oxidized form of the mediator.

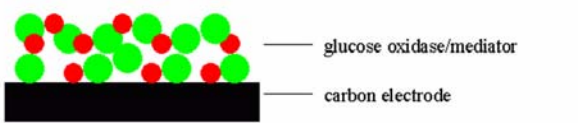

Figure 2-3. *Mediated model of glucose sensor*

Some of the advantages of the mediated sensor are as follows:

- The reaction of GOD with mediator is much better defined. There is no need to worry about variable oxygen concentrations in the sample, just add a known, constant amount of mediator.
- Mediators can be reoxidized at an electrode at less extreme potentials than are necessary for hydrogen peroxide. This partially eliminates *electrochemical interference* caused by substances frequently found in the blood sample such as uric acid, vitamin C, and paracetamol that break down electrochemically and thus give interfering signals under conditions for H_2O_2 detection at a platinum electrode.

Commercial Mediated Biosensors

The commercial reality of the mediated sensor came with the foundation of Genetics International (later to change name to Medisense) and the launch of the pen-sized Exactech glucose sensors in 1987. The system consists of small, disposable, single-use, glucose-sensitive electrodes (based on a mixture of GOD and mediator in a conductive carbon-paste binder) and the corresponding pen-sized (later pocket-calculator-sized) meter containing the electronics and an LCD display. Using this system, the diabetic pricks the finger, obtains a small drop of blood, deposits it on the sensor strip, and within 60 seconds the blood glucose concentration is displayed.

The configuration of mediated sensors lends itself to mass production of single-use, disposable sensor strips using screen-printing and other thick-film techniques, such as inkjet printing. Yet, Medisense-type glucose sensors still occupy less than 10% of a billion-dollar world-wide market. Rumor has it that huge marketing efforts have been invested to win over patients (and perhaps more importantly prescribing doctors) from the traditional reflectometry-based kits. The most telling sign that the glucose biosensor should be qualified as hard-won success is that even companies such as Boehringer Mannheim, the dominant force in reflectometry, have since launched their own biosensor glucose tests.

One Biosensor Success Story

The amperometric glucose biosensor provided rapid and accurate diagnosis in a compact package featuring user-friendly instrumentation. The technical evolution of the glucose biosensor progressed hand-in-hand with its commercial exploitation, and as a result became one of the most successful commercial biosensor developments to date. The challenge for biosensor researchers today is to repeat this success story in other diagnostic and sensing domains.

If we look at the glucose biosensor development, we can identify several serendipitous circumstances that contributed significantly to the successful development and eventual commercialization of the Clark electrode. First, GOD happens to be cheap and easy to obtain. Additionally, GOD is one of the most robust enzymes known—able to withstand greater extremes of pH, and possessing greater ionic strength and temperature resilience than most other enzymes. The unique strength of GOD allowed for less stringent conditions during the manufacturing process, as well as relatively

care-free storage and use by the home-user of the biosensor. Last, the concentration range of glucose with which GOD reacts optimally happens to coincide with the range of concentrations encountered in human blood.

However, amperometric technology measures only a small percentage of the glucose and uses a multiplier to convert this to a numerical value. Therefore, blood glucose readings may be affected by environmental temperature, hematocrit, medications, and other factors. Also, small samples may result in inaccurate readings because of a weak signal being generated.

Next Generation Biosensors

Recently, another method for measuring blood glucose levels has been developed, using coulometry. Coulometry converts all the glucose in a blood sample into an electrical current and is not affected by other medications or conditions the patient may have. Coulometry allows the patient to use the smallest sample size of any available technology.

To determine the concentration of analyte (*e.g.*, glucose) in the sample by coulometry, the charge passing or projected to pass between the working electrode(s) and counter electrode(s) during electrolysis of the analyte is determined. Knowledge of the charge and the volume of the sample chamber permit the calculation of the concentration of the electrolyzed analyte in the sample. This charge can be determined by several methods. For example, the charge can be measured directly. This can be accomplished using a coulometer and known coulometric techniques. Typically, the charge is measured during the complete or nearly complete electrolysis of the analyte.

Coulometric Biosensors

This measurement technique utilizes current measurements obtained at intervals over the course of the assay, to determine analyte concentration. These current measurements are integrated over time to obtain the amount of charge, Q, passed to or from the electrode. Q is then used to calculate the concentration of the analyte (C_A) by the following equation (when the redox mediator is non-leachable):

$$C_A = \frac{Q}{nFV}$$

where:

- n is the number of electron equivalents required to electrolyze the analyte
- F is Faraday's constant (approximately 96,500 coulombs per equivalent)
- V is the volume of sample in the measurement zone

When using a diffusible mediator, the concentration of the analyte can be obtained from the following equation:

$$C_A = \frac{Q_{tot} - Q_{back}}{nFV}$$

where:

- Q_{tot} is the total charge transferred during the measurement
- Q_{back} is the amount of charge transferred that was not due to the analyte, (that is, charge transferred by the shuttling of the diffusible mediator between the working electrode and the counter electrode)

In at least some instances, the sensor is constructed so that the background charge is at most 5 times the size of the charge generated by electrolysis of an amount of analyte.

Signal to Background Signal Ratio

One example of a method for determining the ratio of background signal to signal generated by electrolysis of the analyte is described as follows for the facing electrode pairs. If the shuttling of the redox mediator is not disabled by the applied potential, the charge that results from the shuttling of the redox mediator may be represented by the following formula:

$$Q_{back} = \frac{AFD_M \cdot C_M}{d} \cdot tn_M$$

where:

- A is the area of the working electrode
- F is Faraday's constant (96,500 coulombs/equivalent)
- D_M is the effective diffusion coefficient of the redox mediator
- C_M is the concentration of the redox mediator in the measurement zone
- d is the distance separating facing electrodes; t is the amount of time for the measurement
- n_M is the number of electrons gained or lost by the redox mediator

Additionally, the charge of the analyte, for example, glucose, when the analyte is electrooxidized to about 90% completion in the measurement period may be represented by the following formula:

$$Q_G = Ad(0.90)C_G \cdot n_G F$$

where:

- A is the area of the working electrode
- d is the distance separating facing electrodes
- C_G is the concentration of glucose
- n is the number of electrons needed to electrolyze the analyte (for example, 2 electrons per glucose molecule)

- F is Faraday's constant

Note: When C_G is 5 m_M (or 5 x 10^{-6} moles/cm3)
t is 60 seconds
n_G is 2
n_M is 1

The ratio of charge from the redox mediator to the charge from electrooxidation of the analyte may be represented by the following formula:

$$\left(\frac{Q_{back}}{Q_G}\right) = \left(\frac{D_M \cdot C_M}{d_2}\right) \cdot \left(\frac{tn_M}{(0.9)n_G \cdot C_G}\right) = \left(\frac{D_M \cdot C_M}{d_2}\right) \cdot (6.7 \cdot 10^6)$$

Example #1:

- if the ratio of Q_{back} /Q_G is 5
- then (D_M C_M)/d_2 is 7.5 x 10^{-7} moles/(cm^3 sec)

Example #2:

- if the ratio of Q_{back}/Q_G is 1
- then (D_M C_M)/d_2 is 1.5 x 10^{-7} moles/(cm^3 sec)

Example #3:

- if the ratio is 0.1
- then (D_M C_M)/d_2 is 1.5 x 10^{-8} moles/(cm^3 sec)

Thus, depending on the ratio desired, a sensor may be configured to have the desired ratio by choosing D_M, C_M and d accordingly. For example, the concentration of the redox mediator may be reduced (that is, C_M may be reduced). Alternatively, or additionally, the diffusion of the redox mediator may be reduced by, for example, having a barrier to the flow of the diffusible mediator to the counter electrode (that is, reduce the effective diffusion coefficient of the redox mediator—D_M). Other sensor configurations are also suitable for controlling the ratio of background signal to signal generated by the analyte and will be described below.

The background charge, Q_{back}, can be accounted for in a variety of ways. For example, Q_{back} can be made small by:

- Using only limited amounts of diffusible redox mediator,
- Providing a membrane over the counter electrode that limits diffusion of the redox mediator to the counter electrode, or
- Having a relatively small potential difference between the working electrode and the counter electrode

Other examples of sensor configurations and methods suitable for reducing Q_{back} include:

- Those already described such as sensors having a redox mediator reaction rate at the working electrode that is significantly faster than that at the counter electrode

- Immobilizing the redox mediator on the working electrode
- Having the redox mediator become immobilized on the counter or counter/reference electrode upon its reaction at the counter or counter/reference electrode
- Slowing the diffusion of the redox mediator

Alternatively, the sensor may be calibrated individually or by batch to determine a calibration curve or a value for Q_{back}. Another option is to include a second electrode pair that is missing an item necessary for electrolysis of the analyte, such as, for example, the second electron transfer agent, so that the entire signal from this second electrode pair corresponds to Q_{back}.

Coulometric Measurement Considerations

For coulometric measurements, at least 20% of the analyte is electrolyzed. Preferably at least 90% of the analyte is electrolyzed. The charge can then be calculated from current measurements made during the electrochemical reaction, and the concentration of the analyte is determined using the equations above.

The completion of the electrochemical reaction is typically signaled when the current reaches a steady-state value. This indicates that all or nearly all of the analyte has been electrolyzed. For this type of measurement, at least 90% of the analyte is typically electrolyzed—and often near 100%.

For coulometry, it is typically desirable that the analyte be electrolyzed quickly. The speed of the electrochemical reaction depends on several factors, including the potential that is applied between the electrodes and the kinetics of reactions. Other significant factors include the size of the measurement zone and the presence of sorbent in the measurement zone.

In general, the larger the potential, the larger the current through the cell (up to a transport limited maximum) and therefore, the faster the reaction will typically occur. However, if the potential is too large, other electrochemical reactions may introduce significant error in the measurement. Typically, the potential between the electrodes as well as the specific redox mediator and optional second electron transfer agent are chosen so that the analyte will be almost completely electrolyzed within about 1 minute.

In some cases, the analyte is only partially electrolyzed. The current is measured during the partial reaction and then extrapolated using mathematical techniques to determine the current curve for the complete or nearly complete electrolysis of the analyte. Integration of this curve yields the amount of charge that would be passed if the analyte were completely or nearly completely electrolyzed and, using the equations above, the concentration of the analyte is calculated.

Advantages of Coulometry

Although coulometry has the disadvantage of requiring the volume of the measured sample be known, coulometry is a preferred technique for the analysis of the small sample because it has the advantages of:

- No temperature dependence for the measurement

- No enzyme activity dependence for the measurement
- No redox-mediator activity dependence for the measurement
- No error in the measurement from depletion of analyte in the sample

LAB MEETING #1

Before arriving for this lab, it is imperative that you have read the introduction to this lab (starting at "Introduction to Biosensors" on page 2-2), and that you have an understanding of the underlying principles employed by the sensor during glucose measurements.

Note: During this lab you will not work with blood. Our glucose measurements will be performed upon a glucose solution that is made with water and glucose.

CAUTION:
You may test *only* the glucose levels of the glucose solution provided by your TA.

Introduction

In the United States alone, over 18 million people have either Type I or Type II diabetes. Diabetes is a disease in which the body ceases to regulate the concentration of glucose in the bloodstream, potentially causing serious physiological complications, such as:

- Heart disease
- High blood pressure
- Blindness
- Renal failure
- Nervous system damage
- Amputations
- Complications during pregnancy

Glucose Monitoring Systems

A reliable glucose monitoring system that is accurate and easy to use is of crucial importance in the mainetenace of stable glucose levels in a diabetic's bloodstream. To date, science has made great strides in bringing affordable glucose monitoring systems to the public, but so far all commerical systems have proven flawed to one degree or another. The *perfect* glucose monitoring system is yet to hit the market.

Glucose Levels in Blood

The normal fasting glucose range for a non-diabetic adult is 70 mg/dL to 110 mg/dL (milligrams per deciliter of solution). One to two hours after meals, normal glucose values should be less than 120 mg/dL. A low glucose level in the bloodstream is known as hypoglycemia; a high glucose level is known as hyperglycemia.

Lab #1 Procedure

During this lab, you will measure the glucose levels in a solution provided to you. To make the testing more true to real life, we will introduce substances into the solution that may potentially cause a deviation in the reading. Your task will be to measure and record glucose levels in your solution while observing the effects of the introduced substances and drawing conclusions about their effects on the measurement process.

The following sections are organized as follows:

- "Using the Glucose Meter" on page 2-11
- "Testing Your Glucose Solutions" on page 2-12

Using the Glucose Meter

This lab requires the use of a blood glucose meter. Though the meter is relatively easy to use, improper use of the glucose meter will adversely affect your sample analysis. Take a few moments and read over the following section to become familiar with the Freestyle® blood glucose meter.

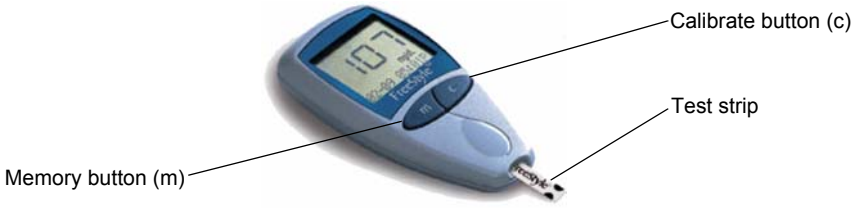

Figure 2-4. *Freestyle glucose meter*

Meter Handling Precautions

Observe the following precautions while working with the glucose meters:

- Use each test strip immediately after removing it from the vial.
- After removing a test strip from the vial, immediately replace the vial cap and close it tightly.
- Touch the test strip only with clean, dry hands.
- Do not bend, cut, or alter a FreeStyle® test strip in any manner.
- Store the test strips away from direct sunlight and away from heat.

- The test strips are for single use only.

Running a Glucose Level Test

In lab we will use the FreeStyle® glucose meter manufactured by TheraSense®. The lances have been removed from the kits because they are *not* needed for this lab. If for any reason you find lances in your kit, report this to your TA immediately.

To Test a Sample With the Glucose Meter:

1. Remove a strip from the storage vial.
2. Slide the strip into the meter; the meter will turn on.
3. Check the code displayed on the meter against the code printed on the vial you took the sample from (for example, **Code 16**).
   - If the codes match proceed to the next step.
   - If the codes do not match, press the **C** button on the front of the meter. This will change the code displayed on the meter. Continue pressing the **C** button until the codes match.
4. When the strip icon appears on the meter display, the meter is ready to test your glucose sample.
5. Gently touch the glucose solution to one edge of the test strip. You may fill the test strip from either side but *not* from both sides.
   - Do not put the sample on top of the test strip.
   - Do not touch the test strip to anything but the glucose solution.
6. The meter will beep when the test strip is full.
7. The meter will display the glucose level as mg/dL (milligrams per deciliter of solution). A deciliter is equivalent to 0.1 liters.

   Note: The meter display will blank after one minute. To turn the display back on, remove the test strip from the meter press the **M** button.

Testing Your Glucose Solutions

Each member of your group will be provided with a stock solution of glucose with a concentration of 60 to 90 mg/dL. You will first test the stock solution to determine the glucose level. Then you will add the stock solution (the *solvent*) to various amounts of the substances (*solutes*) to create the solutions you will test.

To Test Your Glucose Solution With Ascorbic Acid:

1. Locate 3 beakers and some ascorbic acid.
2. Pour glucose solution in each of the beakers.
3. Add enough ascorbic acid to the solution in the beakers so that you have:

- 1 mg/mL concentration the first beaker
- 2 mg/mL concentration in the next beaker
- 3 mg/mL concentration in the last beaker

4. Take measurements of each solution with the glucose meter and record the results in Table 2-1.
5. Clean your beakers with tap water and dry them.

To Test Your Glucose Solution With Galactose:

1. Pour solution in each of your clean, dry beakers.
2. Add enough galactose to the solution in the beakers so that you have:

- 1 mg/mL concentration the first beaker
- 2 mg/mL concentration in the next beaker
- 3 mg/mL concentration in the last beaker

3. Take measurements of each solution with the glucose meter and record the results in Table 2-1.
4. Clean your beakers with tap water and dry them.
5. Repeat this procedure with maltose.

Table 2-1. *Measurement of glucose concentrations*

Substance	Glucose Concentration	Solute Concentration	Measurement	Deviation from the Ideal
Ascorbic Acid				
Galactose				
Maltose				

Questions to Consider

- Did you find any of the substances difficult to measure? Why?
- What substance caused the greatest deviation within your results? What do you suppose the reason for this is?
- What is the difference between glucose and maltose, glucose and galactose? How did the glucose sensor react to these substances?

Biomaterials

In this section you will prepare a variety of biomaterials in the form of films and determine their tensile properties. Materials you will prepare include hydrogels and composites. After preparing and testing your own materials, you will analyze commercially available biomaterials in the same manner. Your report will address the suitability of materials produced in the lab for use in applications such as bone replacement, contact lenses (hard & soft), and wound healing films (internal and external).

SECTION CONTENTS

INTRODUCTION TO BIOMATERIALS TESTING

Biomaterials testing is a discipline that borrows from many diverse fields of study, such as biology, materials science and engineering, mechanics, computer science, electronics, and mathematics. Situated within the area of biomaterials testing is the emerging field of tissue engineering which combines biomaterials and living cells to create matrices of artificial tissue for medical applications. Some of the areas of concern of this field are the biocompatibility of materials, the design of implants, the testing of novel materials, and the form and function of therapeutic tissues and devices.

Some common devices that include biomaterials are contact lenses, hip and knee implants, and stitches. When designing biomaterials some of the key considerations are:

- Necessary period of use
- Potential toxicity
- Cost
- Strength
- Failure rates
- Biocompatibility

Most of these considerations are functions of the effects of stress upon biomaterials. In this lab, you will stress gelatinous films and selected commercially available biomaterials to measure how they react when strained. Your intention in doing this is to determine the usefulness of these biomaterials for various applications in the biomedical engineering field.

Mechanical Properties of Materials

While solid materials may possess a variety of testable properties, (mechanical, chemical, thermal, acoustic, optical, electrical, and magnetic) most often in biomedical applications you will be interested in measuring strength (mechanical) and reactivity (chemical) of a material. In this lab, we will examine one method of measuring biomaterial strength. The basic experiment for determining mechanical properties is the tensile test.

The Tensile Test

A tensile test, also known as tension test, is the fundamental mechanical test you can perform on a material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate.

You can learn a lot about a substance from tensile testing. As you continue to pull on the material until it breaks, you will obtain a good, complete tensile profile. A curve will result showing how it reacted to the forces being applied. The point of failure is of much interest and is typically called its *Ultimate Strength* or UTS.

Hooke's Law

For most tensile testing of materials, you will notice that in the initial portion of the test, the relationship between the applied force, or load, and the elongation the specimen exhibits is linear. In this linear region, the line obeys the relationship defined as "Hoke's Law" where the ratio of stress to strain is a constant. E is the slope of the line in this region where stress (s) is proportional to strain (e) and is called the *Modulus of Elasticity* or *Young's Modulus*.

$$E = \frac{tensile\ stress}{tensile\ strain}$$

$$tensile\ stress = \frac{tensile\ force}{cross\ section\ area} = \frac{Mg}{A}$$

$$tensile\ strain = \frac{extension}{original\ length} = \frac{l}{L}$$

Modulus of Elasticity

The modulus of elasticity is a measure of the stiffness of the material, but it only applies in the linear region of the curve. If a specimen is loaded within this linear region, the material will return to its exact same condition if the load is removed. At the point that the curve is no longer linear and deviates from the straight-line relationship, Hoke's Law no longer applies and some permanent deformation occurs in the specimen. This point is called the *elastic*, or *proportional, limit*. From this point on in the tensile test, the material reacts plastically to any further increase in load or stress. It will not return to its original, unstressed condition if the load were removed.

Yield Strength

A value called *yield strength* of a material is defined as the stress applied to the material at which plastic deformation starts to occur while the material is loaded.

Offset Method

For some materials (e.g., metals and plastics), the departure from the linear elastic region cannot be easily identified. Therefore, an offset method to determine the yield strength of the material tested is allowed. These methods are discussed in ASTM E8 (metals) and D638 (plastics). An offset is specified as a% of strain (for metals, usually 0.2% from E8 and sometimes for plastics a value of 2% is used). The stress (R) that is determined from the intersection point "r" when the line of the linear elastic region (with slope equal to Modulus of Elasticity) is drawn from the offset "m" becomes the *Yield Strength by the offset method.*

Alternate Moduli

The tensile curves of some materials do not have a very well-defined linear region. In these cases, ASTM Standard E111 provides for alternative methods for determining the modulus of a material, as well as Young's Modulus. These alternate moduli are the *secant modulus* and *tangent modulus*.

Strain

You will also be able to find the amount of stretch or elongation the specimen undergoes during tensile testing This can be expressed as an absolute measurement in the change in length or as a relative measurement called "strain". Strain itself can be expressed in two different ways, as "engineering strain" and "true strain". Engineering strain is probably the easiest and the most common expression of strain used. It is the ratio of the change in length to the original length. Whereas, the *true strain* is similar but based on the instantaneous length of the specimen as the test progresses, where L_i is the instantaneous length and L_0 the initial length.

$$\alpha = \frac{L}{L_0}$$

$$\varepsilon = \frac{\Delta L}{L_0}$$

Ultimate Tensile Strength

One of the properties you can determine about a material is its *ultimate tensile strength* (UTS). This is the maximum load the specimen sustains during the test. The UTS may or may not equate to the strength at break. This all depends on what type of material you are testing—brittle, *ductile*, or a substance that even exhibits both properties. And sometimes a material may be ductile when tested in a lab, but, when placed in service and exposed to extreme cold temperatures, it may transition to brittle behavior.

Stress and Strain

The extension for a given load varies with the geometry of the specimen as well as its composition. It is, therefore, difficult to compare the relative stiffness of different materials or to predict the load-carrying capacity of structures with complex shapes. To resolve this confusion, the load and deformation can be normalized. To do this, the load is divided by the cross-sectional area available to support the load, and the extension is divided by the original length of the specimen. The load can then be reported as load per unit of cross-sectional area, and the original length of the specimen. The load can then be reported as the elongation per unit of the original length over which the elongation occurred. In this way, the effects of the specimen geometry can be normalized.

Material Stress

Stress is the measure of force applied to a material which results in strain to the material. Stress is defined as force per unit area:

Stress (s) = Normal force (N) / area (m2)

Some typical types of stress include:

- Compression—stress that acts to shorten an object
- Tension—stress that acts to lengthen an object
- Normal—stress that acts perpendicular to a surface (either compressional or tensional)
- Shear—stress that acts parallel to a surface
- Hydrostatic—stress (usually compressional) that is uniform in all directions
- Directed—stress that varies with direction

Mechanical Strain

Mechanical strain is defined as the amount of deformation an object experiences compared to its original size and shape:

$$\varepsilon = \frac{\Delta L}{L_0}$$

For example, if a block 10 cm on a side is deformed so that it becomes 11 cm long, the strain is (10-1) / 10 = 0.1. (This is often expressed as a percentage, thus: 0.1 * 100 = 10%.)

Mechanical strain is usually described as longitudinal or linear strain. Some common terms associated with discussions of mechanical strain are:

- Elastic—material deforms under stress but returns to its original size and shape when the stress is released. There is no permanent deformation. Some elastic strain, as in a rubber band, can be large.
- Brittle—material deforms by fracturing. Glass is brittle
- Ductile—material deforms without breaking. Metals are ductile. Many materials show both types of behavior. They may deform in a ductile manner if deformed slowly, but fracture if deformed too quickly or too much. Rocks are typically ductile at high temperatures or pressures.
- Viscous—materials that deform steadily under stress. Purely viscous materials like liquids deform under even the smallest stress.
- Plastic—material does not flow until a threshold stress has been exceeded.
- Viscoelastic—combines elastic and viscous behavior. Models frequently assume a viscoelastic earth: the crust flexes elastically and the underlying mantle flows viscously.

PROGRESS AND LAB REPORTS

For due dates of assigned BME 221 laboratory writings, refer to the BME UG Lab web site at:

http://www.engr.utexas.edu/bme/ugrad/UGLab/calendar_221.html

Progress Report

A progress report—in the form of a technical memo—will be prepared individually by each person performing the experiment. The progress reports will be graded will be graded and returned to you by the last lab session of each experiment, so that you may use the reports in preparing for the final lab report.

The progress report should be written after two lab sessions (halfway through the lab). The reports are then due at the beginning of the third lab session. See the specific instructions on technical memos beginning at “Technical Memos” on page 6-9.

Lab Report

In the lab report, it is expected that all details of preparing the films will be described to a level where the work may be duplicated by a reader of the report. A full description of all experimental procedures will also be presented. The results and discussion sections will present and details of the studies (reference the lecture notes for 8/25 for further details). The effect of the amount of gelatin and hydroxylapatite on the gel properties should be discussed. A comparison between experimental materials and commercial materials is expected.

See the specific instructions on lab reports beginning at “Laboratory Notebooks” on page 6-2.

LAB MEETING #1

During the first lab, you will create gelatin-alone films. After creating the gelatin-alone films, you will spend the remaining laboratory time becoming familiar with the Instron® In-Spec 2200 benchtop tester. The best way to learn how to use the benchtop tester is by practicing operating it with a rubberband test load.

The following section describes the procedure for creating your gelatin films. “Operating the In-Spec 2200” on page 3-18 contains information important for configuring and operating your the In-Spec 2200 benchtop tester.

Tensile and Shear Equations

During your tests, you will want to calculate the initial tensile modulus and shear modulus. Use the following equations to help you make these determinations:

Initial tensile modulus:

$$E_0 = \left.\frac{\sigma}{\varepsilon}\right|_{(\varepsilon \to 0)}$$

where:

$$\sigma = \frac{Force}{Area}$$

$$\varepsilon = \frac{\Delta L}{L_0}$$

Initial shear modulus:

$$G_0 = \left.\frac{\sigma}{\alpha - \alpha^{-2}}\right|_{(\alpha \to 1)}$$

where:

$$\sigma = \frac{Force}{Area}$$

$$\alpha = \frac{L}{L_0}$$

Lab Meeting #1 Procedure

The lab work associated with the testing of various biomedical materials requires that you accurately and consistently create weight-percentage films. Data collected from incorrectly developed films will yield unreliable results. Therefore, it is recommended that you take great care in creating your samples, since these samples are the foundation of your lab results.

In today's laboratory, you will create film samples that contain a 10% to 15% weight-percentage of gelatin. During this laboratory only, you will prepare two versions of this film sample: one to be sealed completely during cooling, and one will remain uncovered for 2 to 3 days to allow the film to dry slightly on the upper surface.

Since the accuracy & consistency of your film samples is essential to the success of your laboratory results, you will want to keep meticulous notes detailing the steps you perform in creating your film samples. This will prove crucial to the repeatability of your results as you create and test samples over a period of several weeks.

To Create Your Gelatin-Alone Films:

1. Make calculations to determine the amount of gelatin and water necessary to prepare the 10% to 15% weight-percentage films desired.
2. Measure the correct amount of water in a graduated cylinder, then pour your water into a 250 ml Pyrex Griffin beaker.
   - When determining the amount of water you will need, take into consideration that your film samples will need to cover the bottom of two petri dishes at an approximate thickness of 3 mm.

     Note: If you fill your petri to the factory-created mark on the dish, your sample will be a thickness of approximately 3 mm.

   - You need to prepare enough gelatin solution to create 6 samples 3.0" by 0.75" of each film type (that is, both hydrated and dried film samples). *Each petri dish should yield 6 samples.*
   - You will also need to think of a method for ensuring the samples in all petri dishes are the same thickness, otherwise you run the risk of making meaningless comparisons between samples.
3. Locate a laboratory hotplate/stirrer. Place the hotplate in a level location away from any laboratory electrical equipment.

CAUTION:
SHOCK HAZARD: Working with water around electrical equipment is extremely dangerous. Ensure you do not spill water near any electrical equipment. If you do, immediately notify your TA and take measures to isolate power from the electrical equipment.

4. Place a stirbar in the beaker.
5. Place the 250 ml beaker (with the water in it) on the hotplate and turn the hotplate heat control to **7** or less); turn the stir control to a setting between **3** and **5**.

   Note: Someone must attend the solution while it is heating. *DO NOT* leave the solution unattended for any length of time while it is heating.

CAUTION:
BURN HAZARD: When the hotplate is on, the entire metallic surface of the hotplate is heated. Do not touch the hotplate surface for any reason. NEVER test the temperature of the surface with your skin.

Turn off and unplug the hotplate when not in use. Guard the hotplate until it is cooled so no one else is inadvertently burned by it.

6. Allow the water to heat until small bubbles first appear on the interior walls of the beaker. Weigh the correct amount of gelatin, and slowly add the gelatin to the water.
7. Continue heating and stirring your solution until the gelatin is completely dissolved.

   Note: Do not allow the solution to boil.

8. Turn the hotplate heat control to **Off**. Allow the stirrer to continue as the solution cools to room temperature. This will ensure that the gelatin remains suspended in the water.
9. Using a black Sharpie® pen, label your petri dishes so that you will be able to positively identify your samples next laboratory.
10. Once the solution has cooled to room temperature, carefully remove the beaker from the hot plate. Turn the hotplate off and unplug it.

    Note: For the gelatin-only films this week you will be preparing films that will be sealed completely during cooling and also films that also some that will remain uncovered for 2-3 days to allow the film to harden slightly on the surface.

11. Pour the solution into your petri dishes. Ensure the thickness of the samples in each of the petri dishes will be the same.
12. Let the samples cool at room temperature for 10 minutes, or until the samples have partially gelled.

    Note: Immediately clean your 250 ml beaker after pouring the solution into the petri dishes by rinsing the beaker with water thoroughly. Do not wait until the solution gels on the beaker sides. This will make clean-up considerably more difficult.

13. Seal half of your samples with parafilm, being careful to completely seal all edges. Place the labeled samples in the refrigerator on the shelf marked with your lab day.
14. Place the petri dish lid of the remaining samples under the petri dish bottom, and place these labeled samples in the refrigerator on the shelf marked with your lab day.

    Note: Your TA will cover and seal your dry film sample in 2 to 3 days when the sample has dried slightly on the surface.

15. Clean your workstation and all beakers and materials used in creating your samples. Return these clean materials to their proper location.

Once you have cleaned up your workstation, you are ready to begin learning how to use the In-Spec 2200 benchtop tester.

To Operate the In-Spec 2200 Benchtop Tester:

1. Begin by reviewing the information in "Operating the In-Spec 2200" on page 3-18.
2. Once you are familiar with the In-Spec 2200, practice configuring and running a tests on the benchtop tester using a rubber band.
   a. Position the benchtop tester clamps approximately 1" apart.
   b. Place a rubber band between the clamps, ensuring that the rubber band is neither slack nor under tension.
   c. Using the procedure outlined in "Acquiring Data (Running a Test)" on page 3-15 as a guideline, configure your benchtop tester to test the tensile strength of the rubber band by stretching the material 5.0 cm at 0.4 mm/sec.
   d. Experiment with other settings until you feel confident in using the In-Spec 2200 unit.
   e. Practice downloading test results to your desktop computer, importing the results into Excel, and creating a graph.
3. Clean up your workstation.

LAB MEETING #2

During this lab, you will create gelatin-hydroxylapatite films, as well as test the gelatin-only films you created in the previous labs.

Note: You may need to allot some time during this lab session to creating more gelatin-only samples during this lab if your gelatin-only test results are inconsistent, or if you feel you need to repeat your test for another reason.

Lab Meeting #2 Procedure

During this lab you will create gelatin-hydroxylapatite films (at both 10% and 15% gelatin and 5% and 10% hydroxylapatite). You will also test the gelatin-only samples you created during the previous lab.

To Prepare Gelatin-Hydroxylapatite Films:

1. Make calculations to determine the amount of gelatin, hydroxylapatite (HA), and water necessary to prepare the following weight-percentage films:
   - 10% gelatin with 5% hydroxylapatite
   - 10% gelatin with 10% hydroxylapatite
   - 15% gelatin with 5% hydroxylapatite
   - 15% gelatin with 10% hydroxylapatite

You will need to prepare enough gelatin-HA film to cut 6 samples of equal dimensions (3.0" x 0.75") of each film weight-percentage type. All of these films will be sealed after preparation; none will be left open to dry.

Note: Each petri dish should yield 6 samples.

2. Measure the correct amount of water in a graduated cylinder, then pour your water into a 250 ml Pyrex Griffin beaker.
   - When determining the amount of water you will need, take into consideration that your film samples will need to cover the bottom of the petri dish at an approximate thickness of 3 mm.

     Note: If you fill your petri to the factory-created mark on the dish, your sample will be a thickness of approximately 3 mm.

   - You need to prepare enough gelatin solution to create 6 samples 3.0" x 0.75". of each of the weight-percentage. *Each petri dish should yield 6 samples.*
   - You will also need to think of a method for ensuring the samples in all petri dishes are the same thickness, otherwise you run the risk of making meaningless comparisons between samples.
3. Locate a laboratory hotplate/stirrer. Place the hotplate in a level location away from any laboratory electrical equipment.

> **CAUTION:**
> **SHOCK HAZARD: Working with water around electrical equipment is extremely dangerous. Ensure you do not spill water near any electrical equipment. If you do, immediately notify your TA and take measures to isolate power from the electrical equipment.**

4. Place a stirbar in the beaker.
5. Place the 250 ml beaker (with the water in it) on the hotplate and turn the hotplate heat control to **7** or less); turn the stir control to a setting between **3** and **5**.

   Note: Someone must attend the solution while it is heating. *DO NOT* leave the solution unattended for any length of time while it is heating.

CAUTION:

BURN HAZARD: When the hotplate is on, the entire metallic surface of the hotplate is heated. Do not touch the hotplate surface for any reason. NEVER test the temperature of the surface with your skin.

Turn off and unplug the hotplate when not in use. Guard the hotplate until it is cooled so no one else is inadvertently burned by it.

6. Allow the water to heat until small bubbles first appear on the interior walls of the beaker. Weigh the correct amount of gelatin, and slowly add the gelatin to the water.
7. Continue heating and stirring your solution until the gelatin is completely dissolved.

   Note: Do not allow the solution to boil.

8. Add hydroxylapatite to your dissolved gelatin solution.
9. Turn the hotplate heat control to **Off**. Allow the stirrer to continue as the solution cools to room temperature. This will ensure that the gelatin remains suspended in the water.
10. Using a black Sharpie® pen, label your petri dishes so that you will be able to positively identify your samples next laboratory.
11. Once the solution has cooled to room temperature, carefully remove the beaker from the hot plate. Turn the hotplate/stirrer off and unplug it.
12. Pour the solution into your petri dishes. Ensure the thickness of the samples in each of the petri dishes will be the same.

    Note: To ensure the most uniform dispersion of the HA particles within the gelatin matrix, stir the gelatin-HA solution before you pour the solution into petri dishes.

13. Let the samples cool at room temperature for 10 minutes, or until the samples have partially gelled.

    Note: Immediately clean your 250 ml beaker after pouring the solution into the petri dishes by rinsing the beaker with water thoroughly. Do not wait until the solution gels on the beaker sides. This will make clean-up considerably more difficult.

14. Seal your samples with parafilm, careful to completely seal all edges. Place the labeled samples in the refrigerator on the shelf marked with your lab day.
15. Clean your workstation and all beakers and materials used in creating your samples. Return these clean materials to their proper location.

Once you have created your gelatin-HA samples, sealed them and placed them in the refrigerator, and you have cleaned up your workstation, you are ready to test your gelatin-only samples created during the previous lab.

To Test the Strength of Your Gelatin-Only Samples:

Note: Ensure that you have read and understand the procedures for operating the Instron® In-Spec 2200 benchtop tester (see "Operating the In-Spec 2200" on page 3-18). These units are precision test equipment that must be operated correctly or they will become inaccurate and useless to your lab test needs.

1. Collect the gelatin-only samples you created during the previous lab.
2. Using the cutting die, cut your dried film and hydrated film samples into 6 strips of equal dimensions (3.0" x 0.75").
3. "Acquiring Data (Running a Test)" on page 3-15 describes the procedure for running a tensile test.
4. Extend three of your gelatin films at a rate of 0.4 mm / second, and then extend three samples at 0.2 mm / second. Record the sample measurements until the film breaks.
5. "After Running a Test" on page 3-16 describes the procedure for downloading your data to your computer for further analysis.

LAB MEETING #3

During lab meeting #3, you will measure the strength of the gelatin-hydroxylapatite films you created during the previous lab—as well as any of the gelatin-only films that needed redoing. You may need to allot some time during this lab session to creating more gelatin-hydroxylapatite samples during this lab if your test results are inconsistent, or if you feel you need to repeat your test for another reason.

Lab Meeting #3 Procedure

To Test the Strength of Your Gelatin-Hydroxylapatite Samples:

Note: Ensure that you have read and understand the procedures for operating the Instron® In-Spec 2200 benchtop tester (see "Operating the In-Spec 2200" on page 3-18). These units are precision test equipment that must be operated correctly or they will become inaccurate and useless to your lab test needs.

1. Collect the gelatin-hydroxylapatite samples you created during the previous lab.
2. Using the cutting die, cut your dried film and hydrated film samples into 6 strips of equal dimensions (3.0" x 0.75").
3. "Acquiring Data (Running a Test)" on page 3-15 describes the procedure for running a tensile test.

4. Extend three of your gelatin films at a rate of 0.4 mm / second, and then extend three samples at 0.2 mm / second. Record the sample measurements until the film breaks, or you have an extension of 2x the original length.
5. "After Running a Test" on page 3-16 describes the procedure for downloading your data to your computer for further analysis.

LAB MEETING #4

During lab meeting #4, you will measure the strength of 3 commercial biomedical materials. The available materials are:

- Absorbable sutures
- Glove A
- Glove B
- Glove C
- Tubing A
- Tubing B
- Dialysis tubing

You will choose either two of the gloves or both tubing samples; then you may select a third material of your choice.

Note: You may need to allot some time during this lab session to test any extra gelatin-hydroxylapatite samples you may have created during the previous lab session.

Lab Meeting #4 Procedure

To Test the Strength of Your Selected Commercial Biomaterials:

1. Select three commercial biomaterial samples you will test. You may choose either two of the gloves or both tubing samples with the third material being your choice.
2. Decide how you will cut the samples into consistent samples so that you may maximize the number of samples and that the measurements you make are representative of the material.
3. "Acquiring Data (Running a Test)" on page 3-15 describes the procedure for running a tensile test.
4. Extend the samples at a rate of 0.4 mm / second and at 0.2 mm / second. Record the sample measurements until the film breaks or there is an extension of 2x the original length.
5. "After Running a Test" on page 3-16 describes the procedure for downloading your data to your computer for further analysis.

ACQUIRING DATA (RUNNING A TEST)

The basic operation of the Instron® In-Spec 2200 is somewhat intuitive, so this section of the *Lab Handbook* does not begin with an introduction to the hardware and software of the benchtop tester system. Instead, the following section will step you through the process of running a typical test. If you get stuck, or are asked to do something that you do not understand, refer to the section referenced at that step and it will provide helpful information.

Note: Use a rubberband while learning to use the benchtop tester. Please note that you do not need to break the rubberband during these preliminary tests.

To Run a Test Using the In-Spec 2200 Benchtop Tester:

1. Locate the material to be tested and cut out a strip of known width and length for testing.
2. Turn on the In-Spec 2200 benchtop tester.
3. Connect the PDA to the benchtop tester and turn the PDA on.
4. Select the **In-Spec** icon from the PDA main menu.
5. Set the In-Spec application system preferences ("Setting Preferences" on page 3-21).
6. Ensure **Memory Stick Archive** is enabled ("Setting Preferences" on page 3-21).
7. Use the Jog buttons on the benchtop tester control panel to move the actuator to the required position for the beginning of the test ("Benchtop Tester Controls" on page 3-19).
8. Place the sample in the benchtop tester grips—ensure that you do not stress the sample by clamping it too tightly. Similarly, you do not want to clamp the sample too loosely or it may slip during testing.

   You will also want to try to grip each sample with similar tension. Pay close attention to how tightly you clamp the sample so that you may reproduce this for each sample.
9. On the In-Spec application main screen (Figure 3-5 on page 3-21):
   - Tap the **Reset GL** button to zero the actuator reading.
   - Tap the **bal** button to zero the load reading.
   - Select either **Tension** or **Compression**.
   - Set the desired live control settings.
10. Open the PDA In-Spec application control screen and set the parameters for your test ("Setting Test Control Parameters" on page 3-23).
11. Press the **Start/Stop** button on the benchtop tester (Figure 3-2 on page 3-19).

At this point, the test should run and then stop at the desired set point.

After Running a Test

After running a test, you can either:

- View the test results on the **Test Results** screen. See "Loading Files and Viewing Test Results" on page 3-21 for further information.
- Download data results to your computer for long-term storage or further analysis. See "Downloading Data to a Computer" on page 3-16 for further information.

Downloading Data to a Computer

After saving test data to a file in the PDA, you can download the data to your computer for long-term storage, or further analysis. The steps for transferring PDA database files to your computer are as follows:

1. Connect the PDA to your computer
2. Copy the PDA database files to your computer
3. Convert the PDA database files to text-only files (*.txt*)
4. Create a spreadsheet and import the text-only files

The following sections describe the procedure for downloading PDA database files to your computer in detail.

PDA Data Files

To download the PDA data files, your computer must be configured to perform a memory stick import (that is, your computer must be able to connect to and read the PDA device like an external storage device that can be copied from or pasted to). PDA data files (called PDA database files) copied from the PDA and pasted to your computer are in an unreadable format, and the database files must be converted to a text file by an application residing on your computer called **MFC Handheld**. Once you have converted the data from a PDA data file to a text file, you may import the data into a spreadsheet (such as Excel®).

Downloading Files from the Memory Stick

Once the your PDA database files are saved to the PDA MS, you are ready to copy your data to your computer using the PDA **MS Import** application.

To Download Saved Data to a Computer:

1. Ensure the PDA is on.
2. Connect the serial end of the serial-to-USB converter cable to the PDA and the other end to a USB port on your desktop computer.
3. Open the **MS Import** application on the main menu of the PDA. If you do not see the **MS Import** icon, ensure that the PDA main menu is set for **All**.

4. A new window opens on the desktop computer containing a folder named **Palm**.
5. Double click the **Palm** folder; then select **Programs** => **MS Files** => **In-Spec**.
6. In the **In-Spec** folder, you will see a list of all the files and applications present on the PDA memory stick (MS). Select the file(s) that represent your data set; copy the files. Save the files in a folder with the named for your lab group (for example, **M1a**, **T2c**, **F1a**, and so on).

   Note: The PDA database file will be named as you named it using the In-Spec control function, but it will also include **-INsc** in the name (for instance, **sc-INSC** and **sc1-INsc**).

7. Using Windows® Explorer®, navigate to a location on your computer you wish to paste the data files to and paste the data files.
8. Once you are certain that you have copied your PDA database files locally, erase all the files on the PDA memory stick. You can do this by selecting all the files listed under the In-Spec folder (**Palm** => **Programs** => **MS Files** => **In-Spec)**, then pressing the **Delete** key on the computer keyboard.
9. Select **Disconnect** on the PDA display and turn the PDA off.

You are now ready to convert your data files to text files and then import them into Excel®.

Converting PDA Database Files

At this stage, the data collected from the PDA is in an unreadable format and must be converted to a text file by the desktop computer application **MFC Handheld**.

To Convert the PDA Database Files and Import Them to Excel:

1. Navigate to the folder where your PDA database files reside.
2. Double-click your PDA database file.

   Note: If the MFC Handheld application does not open when you double-click your file, right-click your PDA database file and in the in the context menu, select **Open With** => **Handheld**

3. The **In-Spec 2200 File Converter** interface opens.
4. Ensure the Output Format selected is **Time, Extension, Load**.
5. Select Open and navigate to the PDA database file you wish to convert; select the file.
6. Select **Save as …**, navigate to the same folder that the source file resides, enter a name for the output file, and select **Save**.
7. The program converts the selected files and saves it as a comma-delimited text file. After you have converted all your PDA database files to comma-delimited text files, close the In-Spec 2200 File Converter program.

8. Open Excel and select **Data** => **Import External Data** => **Import Data** to import your data into Excel.

OPERATING THE IN-SPEC 2200

The In-Spec 2200 is a precision benchtop tester designed to perform tensile or compression tests while placed on a level workbench. The data management system for the IN-Spec 2200 is a personal data assistant (PDA)—in this case, the Sony® Clie™. The PDA software gathers force, displacement, and time test data and displays this data in real-time during testing. Data saved to the PDA can be downloaded to a computer for further analysis or long-term storage. The PDA data downloads in Palm OS format and must be converted by the In-Spec 2200 conversion application into a text file (*.txt*) before your computer can use the file.

In-Spec 2200 Hardware Components

The In-Spec 2200 system is comprised of the benchtop tester and the PDA. Figure 3-1 shows the parts of the benchtop tester.

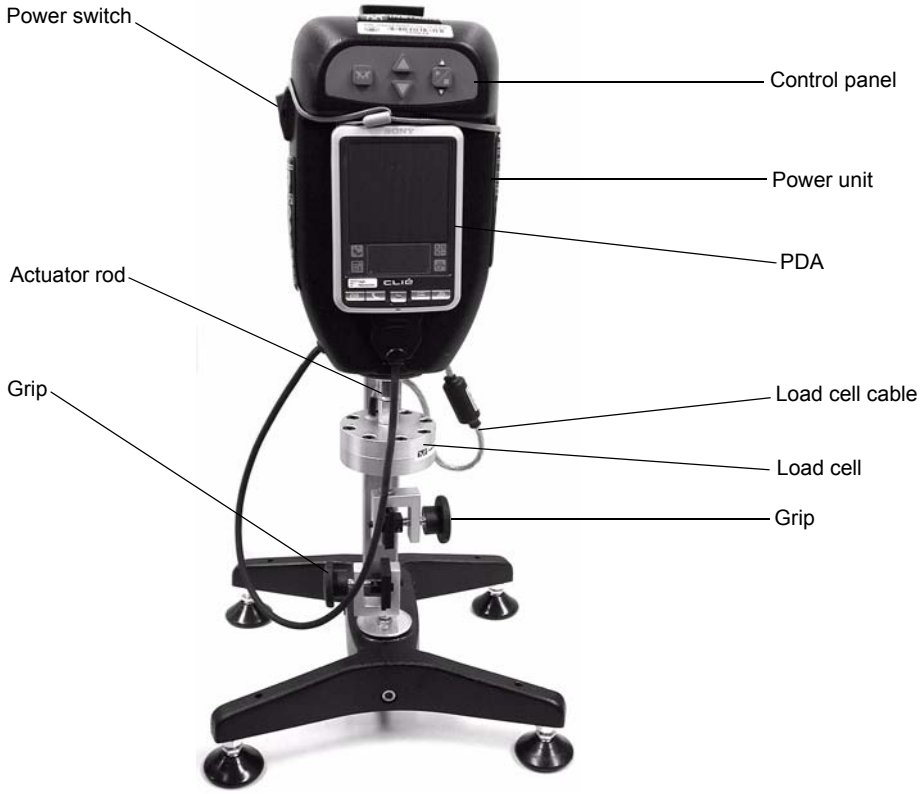

Figure 3-1. *Main components of the benchtop tester*

Benchtop Tester Controls

The control panel and summarized button functions are pictured in Figure 3-2.

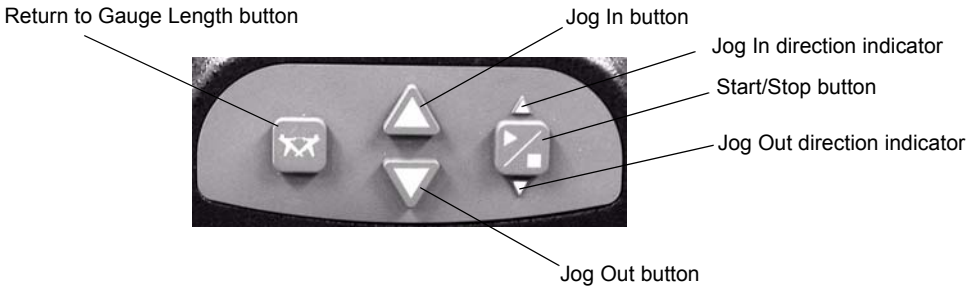

Figure 3-2. *Benchtop tester control panel*

Benchtop Tester Operational Limits

The following table lists the operational limits of the In-Spec 2200 benchtop testers used in our laboratory.

Parameter	Specification
Maximum Load	11.34 kg (25 lbs)
Maximum Force	500 N (110 lbf)
Maximum Extension	100 mm (3.94 in)
Speed Range	1 to 750 mm/min

In-Spec 2200 Data Management Software

The In-Spec 2200 system data management software is the In-Spec application, which resides in the PDA.

In-Spec Main Screen

The main screen is the first screen that displays after you open the In-Spec PDA application. Figure 3-3 shows the main elements of the In-Spec PDA main screen.

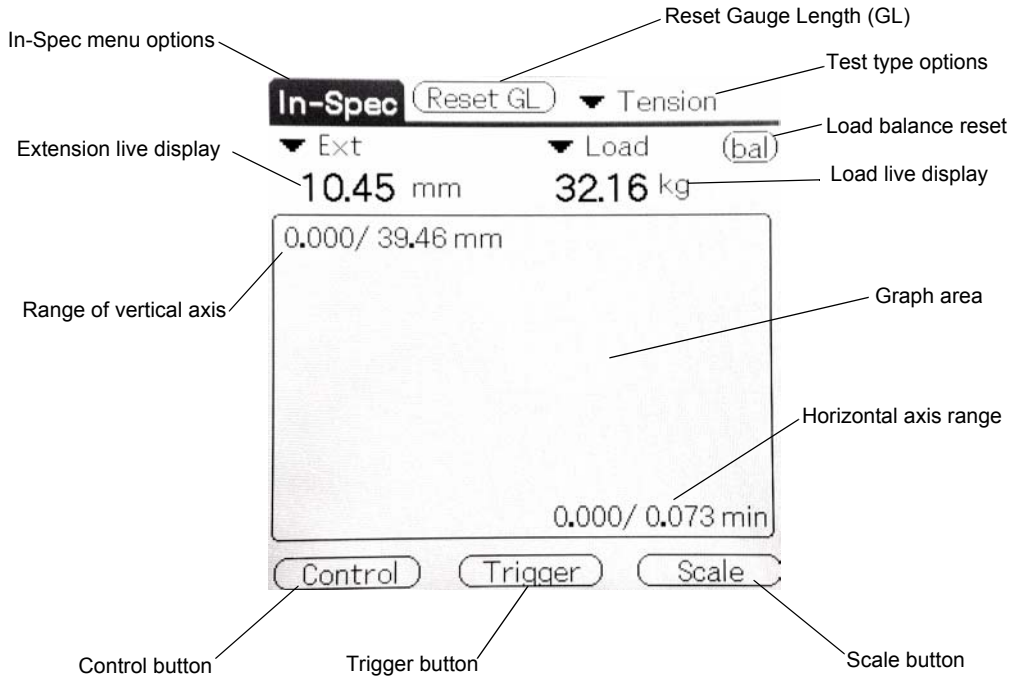

Figure 3-3. *Main screen of the In-Spec PDA application*

Table 3-1. *In-Spec application main screen functions*

Function	Description
In-Spec menu options	Opens the **File** and **Options** sub-menus
Reset GL	Resets length reading to zero
Test type options	When **Tension** is selected: • Positive numbers in the graph and data indicate tensile load (or tensile extension) • Negative numbers indicate compressive load (or compressive extension) When **Compression** is selected: • Positive numbers in the graph and data indicate compressive load (or compressive extension) • Negative numbers indicate tensile load (or tensile extension)
Ext	Mode for the extension live display. The available options are: • **Ext** = Real-time display of actuator • **Ext@Max L** = Displays extension at maximum load • **Ext@Min L** = Displays the extension at minimum load

Table 3-1. *In-Spec application main screen functions*

Function	Description
Load	Mode for load live display. The available options are: • **Load** = Real-time display of load • **Max Load** = Maximum load • **Min Load** = Minimum load
bal	Resets load reading to zero
Graph area	Tap anywhere on the graph to open the Zoom screen
Control	Opens the **Test Control** screen
Trigger	Opens the **Trigger Setup** screen
Scale	Opens the **Axis Scale Setup** screen

Loading Files and Viewing Test Results

You may load a file saved from a previous test, or view the results from a previous test while running the In-Spec application on your PDA by selecting **File** from the In-Spec main screen.

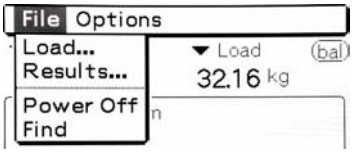

Figure 3-4. *In-Spec application main screen* ***File*** *menu*

Setting Preferences

You can set the default units of measure for the tests you will perform by selecting **Options** from the In-Spec main screen. For our purposes, you will want to select the following units of measure:

- **Time** = seconds (**sec**)
- **Extension** = millimeters (**mm**)
- **Load** = newtons (**n**)

Note: Never select the **Calibrate Load** option. Doing so will cause the In-Spec 2200 system to become uncalibrated, and as a result, unusable.

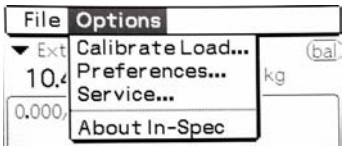

Figure 3-5. *In-Spec application main screen* ***File*** *menu*

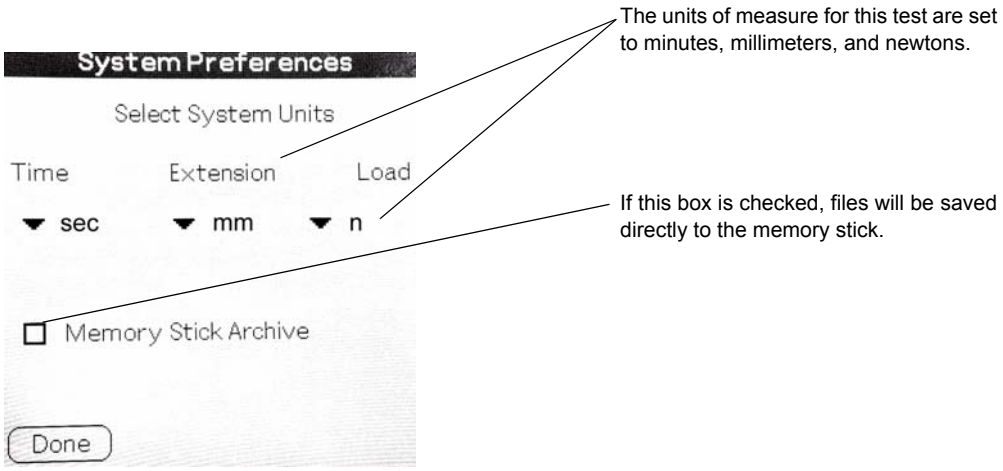

Figure 3-6. *In-Spec application* ***System Preferences*** *screen*

DATA ACQUISITION SETUP

You may customize your data acquisition process using the PDA In-Spec application. The following sections describe the options you have in acquiring data with the PDA In-Spec application for your test.

Setting Test Control Parameters

You may access the test control screen by tapping the **Control** button on the PDA main menu. (See Figure 3-3 on page 3-20 for an illustration of the PDA main menu.)

Figure 3-7 provides an illustration of the test control screen; Figure 3-7 provides an explanation of the various functions available with the test control screen.

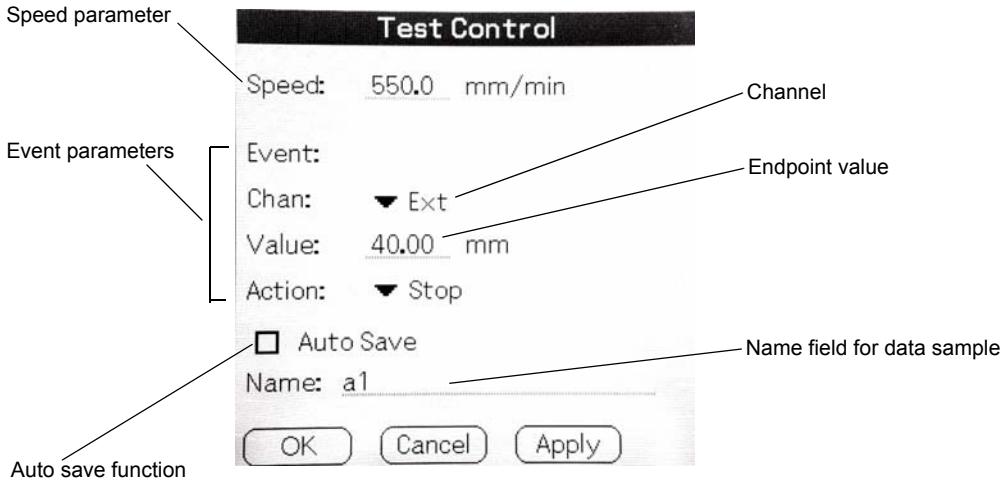

Figure 3-7. *Test control screen*

Table 3-2. *Test control screen functions*

Function	Description
Speed	Sets the speed the actuator will travel during the test
Event	An event is an action that causes the test to stop or change direction. The following parameters are available: • **Channel** = Sets test to **Load** or **Extension** • **Value** = Value at which the test will stop or reverse direction (set point) • **Action** = Sets the action for the end of the test: ▸ **No Action =** Actuator continues past set point and must be manually stopped ▸ **Stop** = Actuator stops at set point ▸ **Reverse** = Actuator reverses direction and the test continues to run recording data *Note:* You may set the test to cycle up to 20 times by setting a number in the **Cycle** field. At the end of the set of cycles, the actuator returns to the starting position and the test ends. ▸ **Return** = The test stops at set point, and the actuator returns to starting position (gauge length).
Auto Save	When checked, this function automatically saves the data at the end of the test. If you run several tests, a successive number will be added at the end of your file name (for instance, a1, a11, a12, a13, ...)

Setting Graph Display Parameters

The In-Spec application allows you to graph your data in custom configurations suitable to your situation. You can set the vertical axis to represent either load or extension; likewise, you can set the horizontal axis to represent extension or time. You can also set the scale for each axis, or you may set scaling to automatic.

To set your graph parameters, tap the **Scale** button on the PDA In-Spec application main menu.

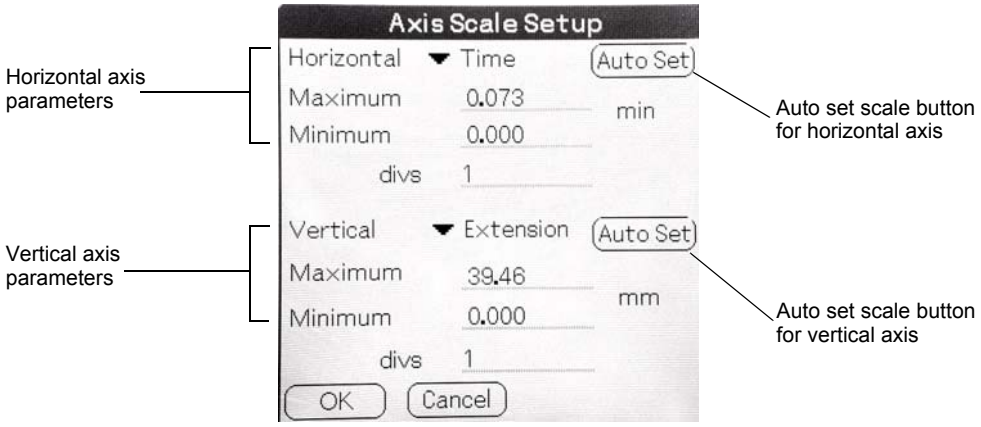

Figure 3-8. *Graph display parameters screen*

Setting Testing Calculations

The PDA In-Spec application can perform several calculations. To view the calculations use the test results screen (at the main menu top-left corner, select **In-Spec** => **Results).**

Table 3-3 lists the available calculations; Table 3-4 lists statistical measurements.

Table 3-3. *Available calculations*

Calculation	Description
Max Load	Calculates the largest load value in the data file
Ext@MaxL	Calculates the actuator extension corresponding to maximum load
Min Load	Calculates the smallest load value in the data file
Ext@MinL	Calculates the actuator extension corresponding to minimum load

Table 3-4. *Available statistical measurements*

Measurement	Description
Mean	Calculates the mean of the sample (group of tests) for each calculation shown
Standard deviation (**Std Dev**)	Calculates the standard deviation of the sample for the calculation shown
Maximum (**Max**)	Determines the largest result of the sample for each calculation shown
Minimum (**Min**)	Determines the smallest result of the sample for each calculation shown

Metabolic Rate

During this lab, you will determine the amount of food (as calories) that must accompany three astronauts as they conduct a space mission that lasts two weeks. Your calculations will be based on study of their respiration while resting and during moderate activity. During the two-week mission, the astronauts should not lose or gain weight. Additionally, due to strict cargo regulations, no extra food will be allowed on the space craft.

To make these calculations, you will need to learn some of the basics of metabolic processes, cellular respiration, and direct and indirect calorimetry.

Direct Calorimetry—Determination of metabolic rate by measuring the temperature change of a closed container containing a metabolizing organism.

Indirect Calorimetry—Determination of metabolic rate by measuring oxygen consumption (as related to ATP production) of organisms that employ cellular respiration—provided that oxygen is not a by-product of respiration (for example, photosynthesis).

Note: This lab is adapted from the metabolism lab first developed by Robert Linsenmeier, Ph.D., of Northwestern University. You can learn about Dr. Linsenmeir is available at: http://www.bme.northwestern.edu/faculty/fac_core_linsenmeier.shtml

SECTION CONTENTS

INTRODUCTION TO METABOLIC RATE

To determine how much food the astronauts will need on their mission, you will first need to determine their *metabolic rate*. Metabolic rate is the rate at which an organism utilizes energy—measured as kilo-calories (Kcal) per hour (or other units of energy per time). As you would expect, muscular activity increases metabolic rate.

Metabolic rate, when measured under various conditions, can vary markedly; thus, it is important to determine the conditions under which the rate is calculated. *Basal metabolic rate* (BMR) is the metabolic rate of humans measured after 12 hours of fasting, at least 8 hours of sleep, and after resting quietly for 0.5 hours. *Resting metabolic rate* (RMR) is the metabolic rate of humans while resting.

Note: Since we will not meet the conditions necessary to measure the basal metabolic rate (BMR) of our human subjects, the resting metabolic rate (RMR) will suffice for the purposes of our lab.

One method we might use to determine metabolic rate would be to place a metabolizing organism in a sealed container and measure the temperature change. This is possible because temperature change and heat production are related by a proportionality constant—heat capacity. This method is called *direct calorimetry*.

Direct calorimetry is not suitable for our small laboratory. To measure the metabolic rate of a college student would require bulky and highly specialized equipment. Fortunately, there is another method that is more suitable to our needs.

Since living organisms use molecular oxygen only for cellular respiration, the rate of oxygen consumption is directly related to the rate of ATP production. Additionally, since oxygen is not given off as a by-product of other cellular reactions (except in cases of photosynthesis), it must be obtained from the environment.

Oxygen consumption can be easily and accurately measured without resorting to technical analytical procedures; thus, the metabolic rates of college students (our future astronauts) can be relatively easily and inexpensively obtained. In this lab we will take advantage of the stoichiometric relationship between energy production and oxygen consumption to measure oxygen consumption—and by extension measure metabolic rate. This is called *indirect calorimetry* and has several variants.

Cellular Respiration

The total process of cellular respiration in any organism using glucose under aerobic conditions can be summarized in the following equation:

$C_6H_{12}O_6 + 6\ O_2 \blacktriangleright 6\ CO_2 + 6\ H_2O$ ΔG = -686 Kcal/ mole of glucose
36 ADP + 36 Pi ▸ 36 ATP ΔG = +262.8 Kcal/ mole of glucose
(7.3 Kcal/ mole of ATP)

Note: These are values of ΔG under standard conditions. Remember that one calorie is the amount of energy needed to heat one gram of water by one degree centigrade (1 ºC). A mole of glucose (180 g) could theoretically heat 6.86 Kg of water from the freezing point to the boiling point.

Determining a Conversion Factor

In order to relate oxygen utilization to metabolic rate, we need to estimate what substrates are actually being used. We really need a value for K—*the number of Kcals liberated for conversion to ATP by 1.0 liter of oxygen.*

Metabolizing Glucose

For glucose we know that if we use up 6 O_2 molecules or produce 6 CO_2 molecules we make about 36 ATP molecules. So, for glucose, we have

(686 Kcal/mole)÷(6 moles of O_2 per mole of ATP) = 114.33 Kcal per mole of O_2

At STP (0 ºC at 1.0 atm), 1 mole of oxygen = 22.4 liters (this is derivable from PV = nRT), so:

$K_{glucose}$ = 114.33 ÷ 22.4 = 5.104 Kcal / liter of oxygen

Metabolizing Fat

Again, this is true only if we are metabolizing only carbohydrate. If we metabolize fat, for instance one of the more common fatty acids, palmic acid, the reactions are:

$CH_3(CH_2)_{14}COOH + 23\ O_2 \blacktriangleright 16\ CO_2 + 16\ H_2O$ -2340 Kcal/mole
129 ADP + 129 Pi ▸ 129 ATP +942 Kcal/mole

We can derive that K will be:

K_{fat} = 4.7 Kcal / liter of O_2

Metabolizing Protein

If we metabolize protein, which usually makes up a small component of the diet, we can't write a single reaction. Some amino acids are converted to alanine before energy is derived, and alanine is usually the amino acid in the highest concentration in the blood.:

$2\ C_3H_7O_2N + 6\ O_2 \blacktriangleright (NH_2)_2CO + 5\ CO_2 + 5\ H_2O$

In addition to CO2 and water, amino acid catabolism produces urea, whose production is expensive energetically. Protein varies in its caloric value but we take the average to be:

$K_{protein}$ = 4.6 Kcal per liter of O_2

Respiratory Quotient (RQ)

What do we do if we have a mixed diet containing all substrates? To consider this, we define the respiratory quotient (RQ):

RQ = Moles of CO_2 produced ÷ moles of O_2 consumed

From the stoichiometry again, RQ for carbohydrate is 1.0, for fat is 0.703, and for protein is 0.833. It turns out that if you measure RQ and know P you can get a value for Kcal/liter pretty exactly:

K = Kcal / liter of O2 = (3.94 + 1.11 RQ)÷(1 + 0.82 P)

(where P is a fraction of the calories derived from protein)

You may wish to see how much K varies if protein varies. K actually is not very sensitive to P. We will not attempt to get an exact value for K, and will instead assume the value often used for a fasting person. As you might expect, this is between the values for carbohydrate and fat.

Our **K** = 4.82 Kcal / liter of O_2

Efficiency should really be measured by considering the energy recovered as ATP divided by the energy available from the substrates. In the formulation, the efficiency of both carbohydrate and fat oxidation is similar—about 40%.

We often discuss efficiency as energy available per gram of substrate. In those units:

- Carbohydrate: 4 Kcal/ g
- Fat: 9 Kcal/ g
- Amino Acids: ~ 4 Kcal/ g, with the range as:
  - 2.12 Kcal/g (glycine)

    to
  - 5.9 Kcal/g (leucine)

Fat is the most efficient way humans store energy because we get more energy per unit weight. The difference is even bigger than the numbers might suggest, because fat is stored as pure fat, whereas carbohydrate and protein have to be dissolved in water three times heavier than the carbohydrate or protein.

Determining Metabolic Rate Using Indirect Calorimetry

As mentioned above, we will not quite meet the conditions needed for measuring BMR, so we are measuring RMR (resting metabolic rate) instead. To relate metabolic rate to oxygen consumption we employ the methods of by indirect calorimetry. To do this, we will assume that:

Volume O_2 consumed = (Volume O_2 inspired) - (Volume O_2 expired)

We will express this relationship as:

Volume O_2 consumed = $F_iO_2 * V_i - F_eO_2 * V_e$

(where F_eO_2 and F_iO_2 are the fractions of oxygen in expired and inspired gas)

After obtaining the volume of O_2 consumed, we use the conversion factor above, K, to determine Kcal/hr required to sustain the astronauts.

Determining Oxygen Content of Inspired and Exhaled Air

We obtain F_iO_2 from known values in the atmosphere: 20.93% in dry air.

We obtain F_eO_2 from an oxygen sensor (oxygen electrode). An oxygen electrode is an electrochemical device in which the reaction at the cathode is:

$2H_2O + O_2 + 4\ e^- \blacktriangleright 4\ OH^-$

This reaction occurs when the cathode is polarized at a negative voltage relative to the anode, which in the system we will use is lead, but may be other metals. One essentially counts the electrons produced in the reaction (*i.e.*, measures current) and this is proportional to the oxygen that reacts. This can be done by polarizing about 0.7 V. One always has to create a calibration curve, but since the current is linearly related to oxygen concentration, a two point calibration curve is sufficient. Oxygen electrodes using this principle, but with slight modifications, are used to measure oxygen in many settings. Blood-gas machines in hospitals use this technique to measure oxygen in arterial blood.

Determining the Volume of Expired Air

We obtain V_e by collecting expired gas in a *Douglas bag*. We then run this through either a spirometer, a homemade displacement device, or a dry gas meter. We have a one-way valve so that inspired and expired gas do not mix.

We will assume that $V_i = V_e$. There is less than 2% error in this, even if we are using fat metabolism and RQ = 0.7. There is no error if RQ = 1.

Accepted Relations for Metabolic Rates

It will be interesting to compare our results to the accepted relations for basal metabolic rates[*]:

- Males: Kcal / 24 hr = 66.473 + 13.75 W + 5.003 H - 6.755 A
- Females: Kcal / 24 hr = 655 + 9.563 W + 1.85 H - 4.676 A

  (where **W** is weight in kilograms, **H** is height in centimeters, and **A** is age in years)

[*]Consolazio, CF, Johnson, RE, Pecora, LJ (1963) *Physiological Measurement of Metabolic Function in Man*. McGraw Hill, NY.

PROGRESS AND LAB REPORTS

For due dates of assigned BME 221 laboratory writings, refer to the BME UG Lab web site at:

http://www.engr.utexas.edu/bme/ugrad/UGLab/calendar_221.html

Progress Report

A progress report—in the form of a technical memo—will be prepared individually by each person performing the experiment. The progress reports will be graded will be graded and returned to you by the last lab session of each experiment, so that you may use the reports in preparing for the final lab report.

The progress report should be written after two lab sessions (halfway through the lab). The reports are then due at the beginning of the third lab session. See the specific instructions on technical memos beginning at “Technical Memos” on page 6-9.

Lab Report

In your brief lab report to Mission Control, you are expected to address the following areas of concern:

- What factors might be expected to influence the caloric requirements of a human during a space mission? Provide a brief explanation of how each factor is expected to influence caloric requirements.
- Your measurements have been made on Earth, and since you do not have any other data available, you must base your conclusions on your terrestrial results. However, you will need to explain to Mission Control what you think might allow you to take RMR data from Earth and assume it is correct for space.
- Using your own data, what are the total energy requirements for the two astronauts in Kcal/day, taking into account both resting and exercise periods (you should assume that the astronauts will exercise for two hours per day against resistance)? Remember, it is imperative that your subjects do not gain or lose weight during this period. State any further assumptions you had to make in arriving at the answer. Present a table of raw data on which you are basing your calculations. Show a sample calculation. Compare the RMR portion of the results to the values expected from the equations in the lab write-up.
- As an example, plan one day’s meals to meet this energy need using data on caloric values in food. The following link provides information on the caloric value of various foods:

  http://www.ntwrks.com/~mikev/chart1.html

  To see what the astronauts really have to choose from, visit:

  http://spaceflight.nasa.gov/shuttle/reference/factsheets/food.html

- NASA has considered the possibility of capturing the potential energy generated by the exercising astronauts to charge batteries. Calculate what efficiency they can expect from a human battery charger.

See the specific instructions on lab reports beginning at "Laboratory Notebooks" on page 6-2.

LAB MEETING #1

During this lab meeting, you will need to calculate what you believe will be the food requirements for your astronaut subjects while resting. You will also want to gather the necessary lab equipment, create a detailed plan for how you want to conduct the lab, and practice calibrating your O_2 sensor.

You will also need to create your hardware interface to couple your O_2 sensor and flow meter with your software monitoring and analysis tools.

Issues to Consider in Performing the Lab

While preparing to perform the lab you will want to consider the following:

- How many measurements do you need to take under resting and exercising conditions in order to get reliable values?
- Should you check over your data before leaving the lab in order to determine whether the data are good, or wait until you are back in your room?
- The Douglas bags can hold about 50 liters. For how long should you collect the gas under resting and exercising conditions?
- During exercise, will it matter when during the exercise you take the sample of expired gas?
- During exercise, do you expect the gas content and the expired volume of expired air to change or just one?
- Do you expect your efficiency (work output/total calories used) to be the same at all work loads?
- Do we have to worry about glycolic metabolism escaping our detection?

Lab Meeting #1 Procedure

1. Create a schedule for performing the lab. Ensure that you are familiar with:
   - The theoretical foundations of the lab (see "Introduction to Metabolic Rate" on page 4-2)
   - The special requirements for the lab report ("Lab Report" on page 4-6)

- The issues to consider in preparing for the lab "Issues to Consider in Performing the Lab" on page 4-7)

2. Using the information provided in "Accepted Relations for Metabolic Rates" on page 4-5, predict the amount of food it will take to sustain your astronauts during a specified period of rest.
3. Survey your parts to ensure that you have the necessary equipment to build the interfaces for your sensors (see "The Oxygen Sensor Hardware Interface" on page 4-8 and "The Flow Meter Hardware Interface" on page 4-9).
4. Build the hardware interface to couple the O_2 sensor and flow meter to the software measurement and analysis tools on your lab computer (see below for the procedures).
5. Practice calibrating your sensors.
6. Return all equipment to the position and condition in which you found it and clean your workstation.

Building Your Hardware Interfaces

For this lab you need to create one hardware interface for the oxygen sensor and another hardware interface for the flow meter.

The Oxygen Sensor Hardware Interface

You will require the following materials to build an interface for the oxygen sensor:

- Vernier 0_2 sensor
- Soldered BTA to DIN converter cable (provided TA)
- NI ELVIS prototyping board
- NI ELVIS workstation
- LabView **02sensor.vi**

To Build an Interface for the Oxygen Sensor:

1. Your TA will provide you with a pre-soldered BTA-to-DIN connector interface.
2. Connect the BTA connector to the Vernier O2 sensor interface cable.
3. On the ELVIS workstation back panel, place the workstation power switch to **ON**.
4. On the ELVIS workstation front panel, place the **Prototyping Board Power** switch to **ON**.
5. Locate the wire on the BTA-to-DIN connector interface cable that is labeled **Ground**. Connect the **Ground** lead to the ELVIS prototyping board pinhole that corresponds to the **DC Power Supplies** (lower-left corner of prototyping board) **GROUND** connection.
6. Locate the wire on the BTA-to-DIN connector interface cable that is labeled **Power Input (+5V)**. Connect the **Power Input (+5V)** lead to the ELVIS

prototyping board pinhole that corresponds to the **DC Power Supplies** (lower-left corner of prototyping board) **+5V** connection.

7. Locate the wire on the BTA-to-DIN connector interface cable that is labeled **Sensor out**. Connect the **Sensor out** lead to the ELVIS prototyping board pinhole that corresponds to the **DMM** (middle-left edge of the prototyping board) **Voltage+** connection.
8. Open your LabView application.
9. Locate and open the **O2sensor.vi** file.
   - A shortcut to this executable may be posted on your desktop, or
   - You may need to copy the VI from the UG Lab library drive, (**Z drive: Library** => **Metabolism** => **LabView)** and copy the VI locally.

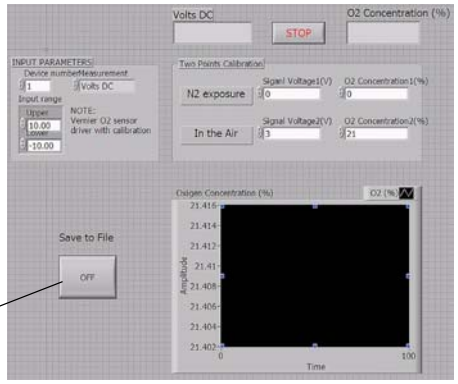

Figure 4-1. *O2sensor.vi front panel*

10. Set **Save to File** to **ON** by clicking the button. This function enables acquired data to be saved into a file for later retrieval and analysis.

This concludes the building of your O_2 sensor interface.

Now you will want to practice performing a two-points calibration of the unit. See "Step 2: Calibrate Test Sensors" on page 4-14 for calibration procedures.

The Flow Meter Hardware Interface

The TSI flow meter is a precision device that must never be exposed to water. Water vapor will destroy the sensitive sensing elements of the device. *Never* breath into the flow meter, or allow any unfiltered air to pass through the flow meter.

You will require the following materials to build an interface for the TSI flow meter:

- TSI flow meter
- Cable with micro-DIN connector at one end
- Soldered cable equipped with female 9-pin sub-D connectors (provided by TA)
- NI ELVIS prototyping board
- NI ELVIS workstation
- **TSIFlow.exe**

To Build an Interface for the TSI Flow Meter:

1. Your TA will provide you with a cable pre-soldered with two female 9-pin sub-D connectors and another cable with a micro-DIN connector at one end and unterminated leads on the other.
2. On the ELVIS workstation back panel, place the workstation power switch to **ON**.
3. On the ELVIS workstation front panel, place the **Prototyping Board Power** switch to **ON**.
4. Using the cable terminated with two 9-pin female sub-D connectors, connect the 9-pin sub-D connector on your desktop computer to the 9-pin sub-D connector on your ELVIS prototyping card.
5. Connect the cable terminated in a micro-DIN connector to the mating connector on the TSI flow meter.
6. Using the unterminated leads on the cable connected to your flow meter, make the following connections:
   a. Connect the **Ground** lead to the ELVIS prototyping board pinhole that corresponds to the **DC Power Supplies** (lower-left corner of prototyping board) **GROUND** connection.
   b. Connect the **Power Input (+5V)** lead to the ELVIS prototyping board pinhole that corresponds to the **DC Power Supplies** (lower-left corner of prototyping board) **+5V** connection.
7. Locate and open the **TSIFlow.exe** file.
   - A shortcut to this executable may be posted on your desktop, or
   - You may need to copy the VI from the UG Lab library drive, (**Z drive: Library** => **Metabolism** => **LabView)** and copy the VI locally.
8. Start reading the flow through the flow meter by toggling **On** and **Off** the soft panel switch.

   Note: For more information about the operation and parameters of **TSIFlow.exe**, see: http://www.tsi.com/flowmetr/downloads/pdffiles/hints.pdf

After you have built and tested your flow meter hardware interface, you will want to practice taking readings from the meter using the TSIFlow soft front panel.

LAB MEETING #2

During this lab, you will collect and analyze expired gas samples from your astronauts while they are resting. You will need to measure and record all the necessary samples before the end of the lab, because you must restore the equipment to its original condition at the end of class.

Note: The next lab is dedicated to the collection and analysis of gas samples from your astronauts while they are exercising.

Lab Overview

The general strategy of this laboratory will be to collect expired gas in Douglas bags, and then to perform measurements on that gas. You will need to measure:

- The time of the gas collection under known physiological conditions, either resting or during moderate exercise.
- Oxygen content of the gas
- Total volume of the expired gas

In addition, we should ideally measure the relative humidity of room air so that we can obtain the actual fraction of inspired oxygen, which will be a little lower than 20.93% due to the presence of water vapor.

Each lab group should make measurements under resting and exercising conditions. It is preferable to make a "good" set of measurements rather than making several "not so good" sets of measurements.

Note: Group members should *not* participate in the exercise portion of the lab if they have any health problems.

Lab Meeting #2 Procedure

You should have already created your hardware interface for coupling the Vernier Company O_2 sensor and TSI flow meter to your lab computer. Additionally, ensure that you have already calculated the expected metabolic rate of your astronauts at rest and arrived at a food requirement (in Kcals) for a specified time period of time.

During this lab you will collect samples from your astronauts while they rest. Ensure that you collect enough samples to ascertain your data is accurate.

The following sections will provide procedures and information important to the execution of this lab.

Overview of Lab Procedure

This lab is difficult in that it requires that you perform several relatively complex tasks to complete the lab. To help you get a picture in your mind, we have provided the following overview. The sections that follow will discuss the procedures in detail.

1. Collect exhaled gas samples (see "Step 1: Collect Exhaled Gas Sample" on page 4-12 for procedural information).
   - Collect samples while the subject is at rest (lab meeting #2).
   - Collect samples while the subject is exercising (lab meeting #3).

   Note: Several samples may be necessary to determine if the measurements exhibit a tolerable level of variation (that is, your samples demonstrate consistency).
2. Calibrate test equipment & test operation of sensors (see "Step 2: Calibrate Test Sensors" on page 4-14 for procedural information).
   - The oxygen sensor is calibrated with nitrogen (0% oxygen) and room air (~20.8% O_2).
   - The flow meter is calibrated to read 0.0 at no flow condition (ends capped).
3. Measure oxygen content (as a percentage) of samples (see "Step 3: Test Oxygen Content (%)" on page 4-17 for procedural information).
4. Measure gas volume (in liters) of samples (see "Step 4: Measure Gas Volume" on page 4-18 for procedural information).
5. Record findings and repeat testing as necessary.

Step 1: Collect Exhaled Gas Sample

The accuracy of your gas volume measurements depends largely upon your ability to handle the gas collection process. Use care in collecting and handling the exhaled gas so that no gas escapes.

To Collect Expired Gas in the Douglas Bag:

1. Empty the Douglas bag of gas as completely as possible.
2. Using the 1.5" corrugated tubing provided, connect the Douglas bag to the headset check valve. You will need a plastic tube insert to mate the connectors. See Figure 4-2 for a picture of this component.

   You will want to ensure that the Douglas bag is attached to the port on the check valve that only allows air to flow into the Douglas bag and not the other way around.

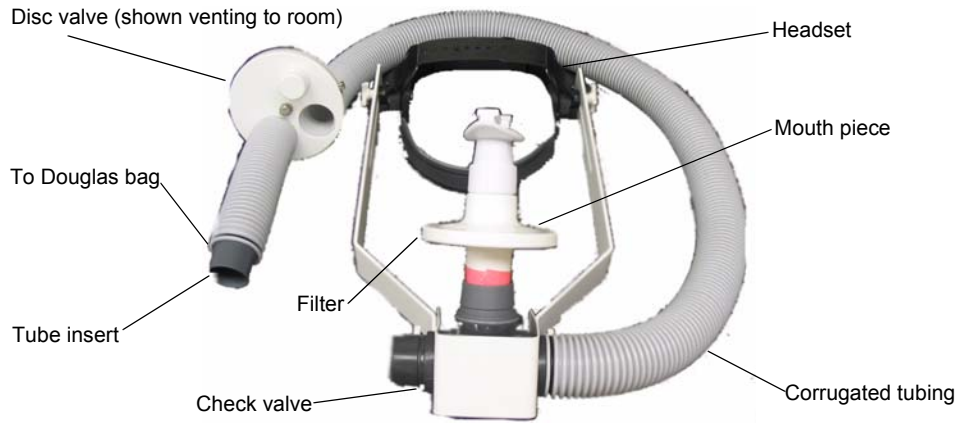

Figure 4-2. *Gas capture apparatus (Douglas bag not pictured)*

3. Locate and attach a new (and clean) mouthpiece and filter to the headset assembly. You will need to apply a thin layer of red tape to the filter pipe stem to ensure a good seal to the check valve assembly.

   Note: Do not attempt to fill the Douglas Bag by blowing directly into the bag. You must only breath into the bag when the filter is properly attached.

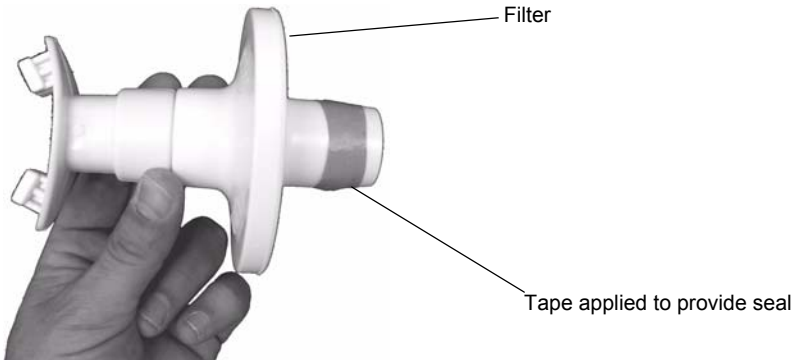

Figure 4-3. *Mouthpiece assembly with tape seal*

4. Rotate the circular valve plate (disc valve) so that gas travelling from the check valve toward the Douglas bag will be vented to the room instead of being allowed to fill the bag (as shown in Figure 4-2).
5. Help your astronaut don the Douglas bag and connected headpiece. Adjust the headgear and Douglas bag straps to fit comfortably. Figure 4-4 shows a student wearing the gas collection apparatus.

   Note: At this point the astronaut is not breathing into the Douglas bag because in the previous step you rotated the circular valve plate to have gas from the mouthpiece to vent to the room.

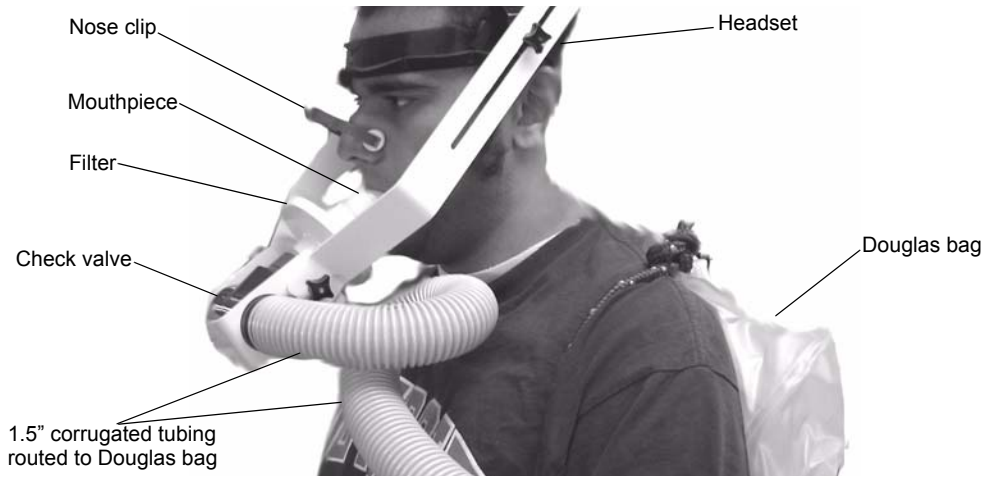

Figure 4-4. *Astronaut wearing the gas collection apparatus*

6. Place a nose clip on the astronaut.
7. Allow the astronaut time to grow comfortable breathing through the mouthpiece.
8. When the astronaut is ready, rotate the circular valve plate to start collecting the exhaled gas sample. Start timing at the point at which you rotate the valve plate to begin collection.
9. Close the valve when you stop timing.
10. Careful to not let gas escape, remove the corrugated tubing from the Douglas bag and promptly insert a rubber stopper to block gas flow.

Figure 4-5. *Stopper shown in Douglas bag vent*

11. If you have a second Douglas bag at your disposal, you may want to collect a second gas sample from your astronaut. Otherwise, help the astronaut doff his gas collection apparatus and prepare to test your sample(s).

Step 2: Calibrate Test Sensors

Accurate calibration of your test sensors cannot be overemphasized. The only way that you will be able to generate accurate and repeatable data from your sensors is after careful calibration.

Note: Even if another group has done this, you should check calibration and adjust as necessary.

In order to calibrate the oxygen sensor, you need to expose the sensor to a 0% oxygen environment to *zero* the software measurement tool. This is done in our laboratory by displacing all the oxygen in a chamber with nitrogen (N_2) and then adjusting the software tool display 0% (since all the gas in the chamber will be N_2, there will be 0% O_2). The flow meter is zeroed by adjusting the reading to zero in a no-flow condition.

To Calibrate Your Oxygen Sensor:

1. Locate a 140 ml syringe and connect a stopcock valve to the end.
2. Connect the syringe to the tubing from the N_2 cylinder located in the lab.

> **CAUTION:**
> **MISSLE HAZZARD: Make sure that you have received training in the use of the regulator on the N_2 tank before attempting to use it. Gas cylinders are potentially very dangerous, with internal pressures as high as 2200 psi.**

3. Open the regulator valve slowly and allow N_2 from the cylinder to flow into the syringe. The plunger of the syringe will be pushed back by the rising gas pressure. When the syringe is full, turn off the valve at the cylinder to arrest gas flow.
4. Close the stopcock on the syringe to ensure that the gas in the syringe is not contaminated by room air.
5. Disconnect the syringe from the cylinder tank tubing.
6. Remove the O_2 sensor from its storage container and place the sensor into the modified syringe that will serve as the sensor chamber.

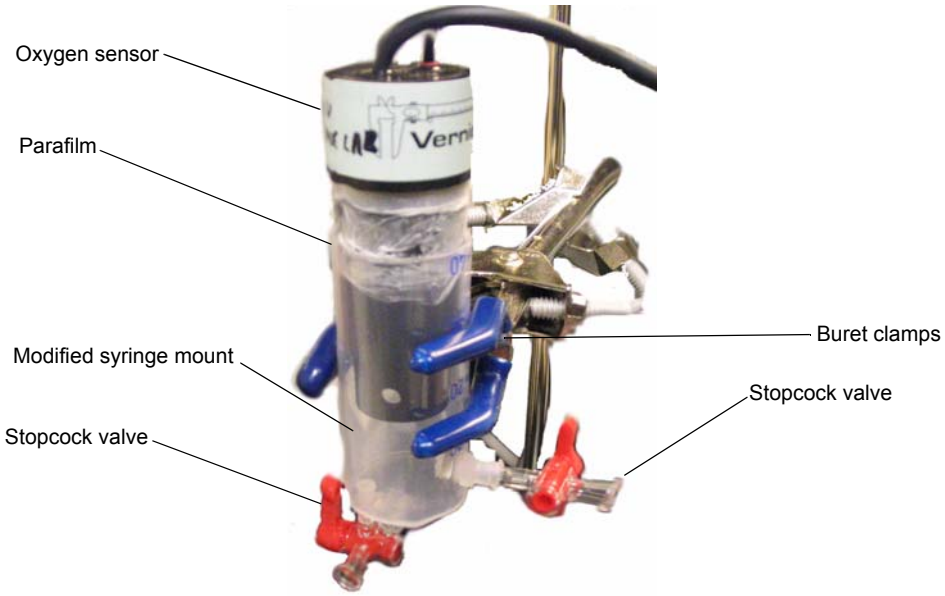

Figure 4-6. *Oxygen sensor mounted in modified syringe*

7. Connect the O_2 sensor to your hardware interface which will couple the sensor signal to your lab computer. Energize the interface to provide power to the O_2 sensor.
8. Allow the sensor to reach a stable reading.
9. Enter the value in the **Volts DC** text box into the In the Air **Signal Voltage2(V)** text box (see Figure 4-7).
10. Enter the value in the **O2 Concentration (%)** text box into the In the Air **O2 Concentration2 (%)** text box (see Figure 4-7).
11. Open both stopcock valves on the O_2 sensor chamber.
12. Connect the stopcock on the syringe filled with N_2 to the stopcock on the test syringe.
13. Slowly inject N_2 into the chamber underneath the gas sensor. When you are certain that you have flushed all of the room air from the chamber, close both the stopcock valves on the chamber.
14. Allow the sensor to reach a stable reading.
15. Enter the value in the **Volts DC** text box into the N_2 exposure **Signal Voltage1(V)** text box (see Figure 4-7).
16. Enter the value in the **O2 Concentration (%)** text box into the N_2 exposure **O2 Concentration1 (%)** text box (see Figure 4-7).

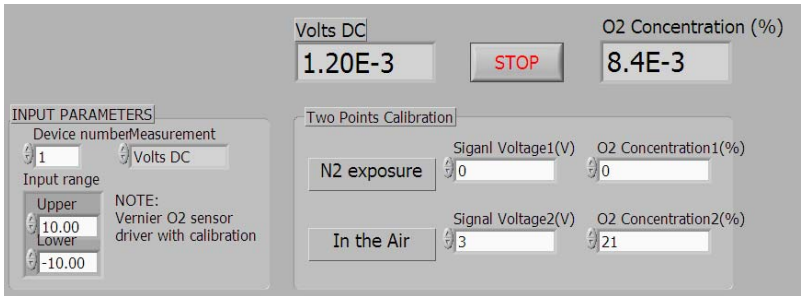

Figure 4-7. *O2 sensor calibration section of the soft front panel*

This concludes the two-point calibration of your O_2 sensor. Now you are ready to test oxygen content of your sample (see "Step 3: Test Oxygen Content (%)" on page 4-17).

To Calibrate Your Flow Meter Sensor:

1. Locate your TSI flow meter and associated cabling.
2. Place the red caps on both ends of the flow meter so that the flow meter is in a no-flow condition.
3. Connect the flow meter output cable to the hardware interface you created during the previous lab meeting.
4. Energize the interface to provide power to the flow meter.

5. Read the output of the flow meter, make adjustments as necessary so that the output reads zero (no flow condition).

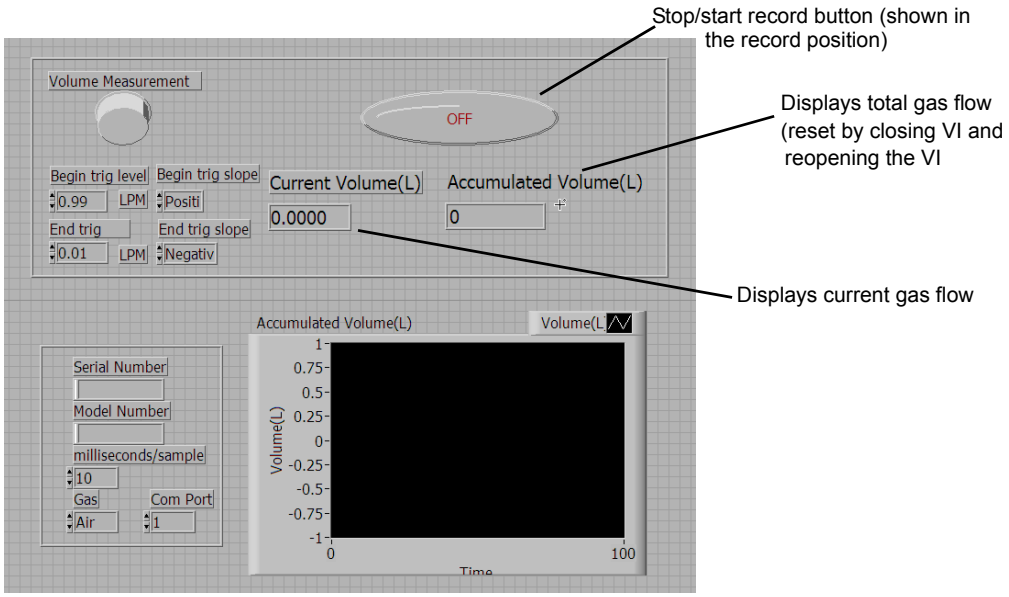

Figure 4-8. *Flow meter front panel showing no flow and no accumulated flow*

This concludes the calibration of your flow meter. You are now ready to use your flow meter to measure the volume of your gas samples (see "Step 4: Measure Gas Volume" on page 4-18).

Step 3: Test Oxygen Content (%)

You will test the oxygen content of your samples using oxygen sensors (oxygen electrodes) made by Vernier Company.

Note: Keep the oxygen sensors upright at all times with the cord facing up.

To Test Oxygen Content of Collected Gas:

1. Ensure you have calibrated your O_2 sensor (see "Step 2: Calibrate Test Sensors" on page 4-14 for calibration information).
2. Using a 140 ml syringe with a stopcock valve attached, draw a sample of expired gas from your Douglas bag (see Figure 4-9).

   Note: Record how much air you draw from your sample for the O_2 test so that you may add this amount to your figure for total volume.

3. Once you have drawn a sample of expired air into the syringe, close the stopcock valves on both the Douglas bag and the syringe; disconnect the syringe from the Douglas bag.

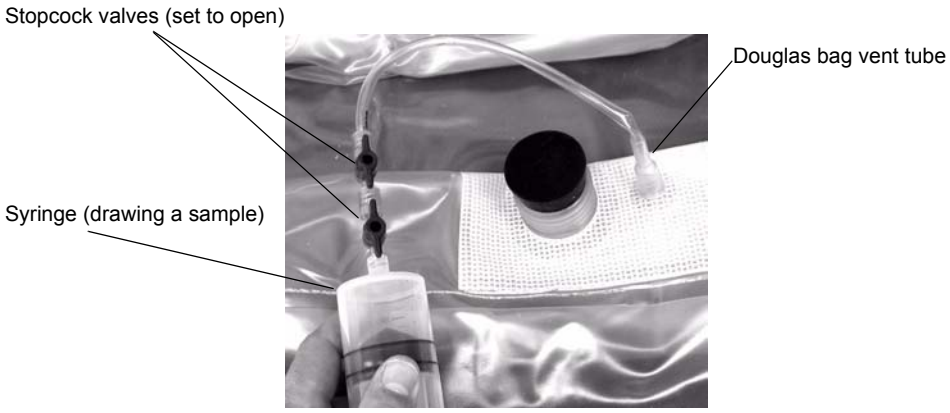

Figure 4-9. *Syringe connected to draw a sample*

4. Connect the syringe to the O_2 sensor chamber, as shown in Figure 4-10.

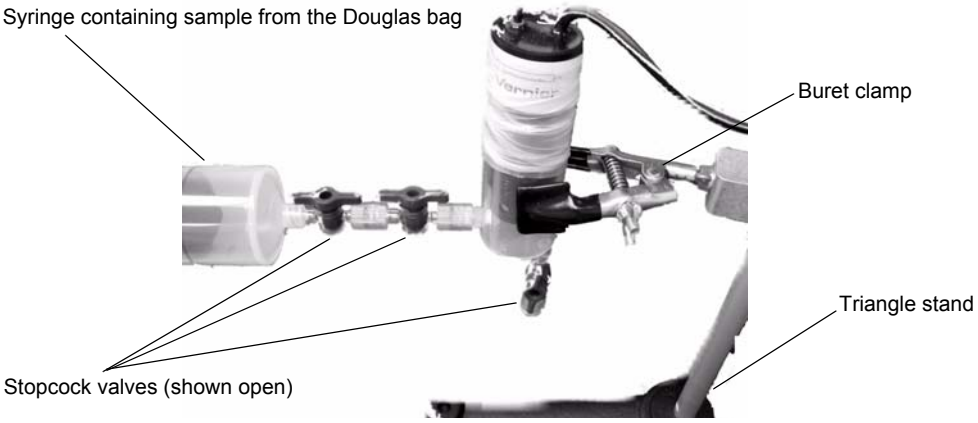

Figure 4-10. *Inserting a gas sample into the oxygen sensor chamber*

5. Ensure all stopcock valves are open. There are three total valves (see Figure 4-10).
6. Slowly inject the sample of expired gas from the syringe into the O_2 sensor chamber. Once you have sufficiently flushed the chamber of room air, and filled it with your sample gas, close the three stopcock valves. Disconnect the syringe from the O_2 sensor chamber.
7. When you have recorded your O_2 measurements, thoroughly flush the sensor with room air.

Step 4: Measure Gas Volume

We are using electronic air-flow meters made by TSI to measure gas volume in the Douglas bags. Using the hardware interface you created last lab meeting, you will integrate the electrical flow signal output from the sensor with your lab computer where software tools will yield a volume signal.

An important aspect of this procedure is that the gas to be measured must be dry before entering the flow meter. To facilitate this, we must connect a chamber containing *Drierite*—a desiccant—preceding the flow meter. As the exhaled gas passes through this chamber, it is dried sufficiently so that it will not damage the flow meter.

Note: The accuracy of your gas volume measurement will depend on how well you emptied the Douglas bag before collecting gas, as well as how thoroughly you are able to empty your sample through your flow meter. Remember that you removed some gas from the Douglas bag for oxygen assessment.

To Measure Your Gas Sample Volume:

1. Locate and assemble the components to create the gas volume testing assembly (see Figure 4-11 for a photograph of this assembly).

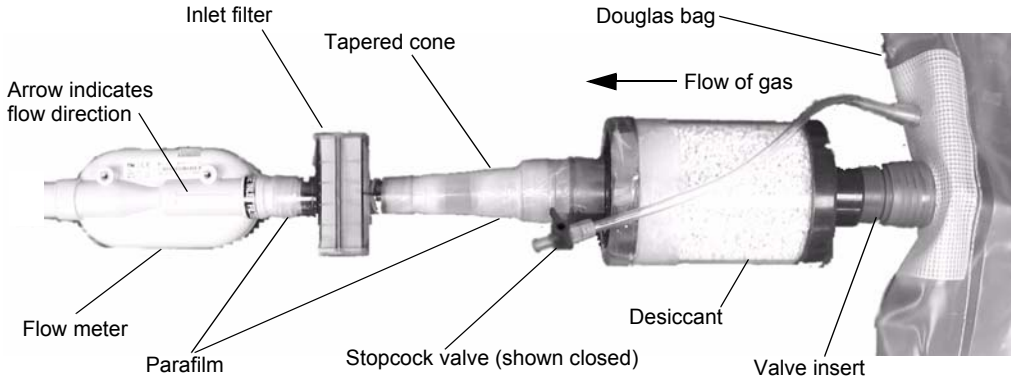

Figure 4-11. *Gas volume testing assembly*

2. Ensure that the desiccant chamber is completely filled, so that no gas may bypass the desiccant.
3. Ensure the arrow stamped on the flow meter casing is pointing in the direction of flow.
4. Apply a layer of parafilm between each component to ensure no gas may leak at the component connections.
5. Ensure that you place an inlet filter at the intake of the flow meter.

> **CAUTION:**
> **Do not operate the flow meter without connecting a full desiccant chamber and inlet filter upstream from the flow meter. Passing gas through the flow meter without either of these components may result in irreparable damage to the flow meter.**

6. Connect the flow meter to your hardware interface and energize the interface.

7. Once you have created the gas volume testing assembly (as shown in Figure 4-11), you have connected the flow meter to your lab computer via the hardware interface, energized the flow meter, and opened the LabView program that will display the output of the flow meter, you are ready to measure the gas sample volume in your Douglas bag.
8. Apply a light and steady pressure on the Douglas bag, forcing all of the gas from the bag.
9. Record your findings and repeat the measurements on any remaining samples you have collected.
10. When finished, return all components to the condition in which you found them. Ensure that you replace the caps on the flow meter.

LAB MEETING #3

During this lab you will collect samples from your astronauts while they exercise moderately. Other than the increased activity of your astronauts, this lab will proceed exactly as the previous lab. Ensure that you collect enough samples to ascertain your data is accurate.

Note: Group members should *not* participate in the exercise portion of the lab if they have any health problems.

Lab Meeting #3 Procedure

During this lab you will collect samples from your astronauts while they exercise moderately. Our exercise will consist of walking up and down a set of stairs at a rate of one stair per two seconds. You will want to adjust your collection time, since your astronauts will breathe faster while exercising. You do not want to let your sample bag fill completely during the test.

Follow the procedure described in "Lab Meeting #2" on page 4-11 for the collection process. Remember that.

LAB MEETING #4

During this lab you will use a commercial pulse oximeter (the Nonin 8600) to acquire metabolic data from your astronauts. You will then compare this data to the results collected from your indirect calorimetry apparatus.

Pulse Oximetry

It is clinically important to know the oxygen saturation of the blood under ambulatory conditions. Low amount of oxygen in the arterial system would result in onset of hypoxia, and could lead to tissue damage. Therefore, a system which would detect the presence of blood circulation as well as the amount of oxygen in the blood is needed. Pulse oximeters are the most commonly used tool for this particular purpose.

Hemoglobin is the protein contained in the red blood cells which help carry the oxygen in the blood. 98% of the oxygen carried by the blood is carried by the hemoglobin while the remaining 2% is dissolved in the plasma portion of the blood. Pulse oximeters take advantage of the fact that the hemoglobin has different light absorption characteristics at different wavelengths.

Optical absorption characteristics of oxygenated and deoxygenated hemoglobin are shown on Figure 4-12. As it can be seen from the traces, the two spectra intersect at the isobestic wavelength of λ=805 nm, where the absorption is independent of oxygen saturation in the blood. Absorption measured at this frequency is used as a reference value. The two spectra differ greatly at λ=660 nm, which used as the measurement point. Commercial unit that is available in the laboratory uses λ=660 nm measurement and λ=910 nm for reference where the choices are dictated usually be the availability of components and competitive patent coverage.

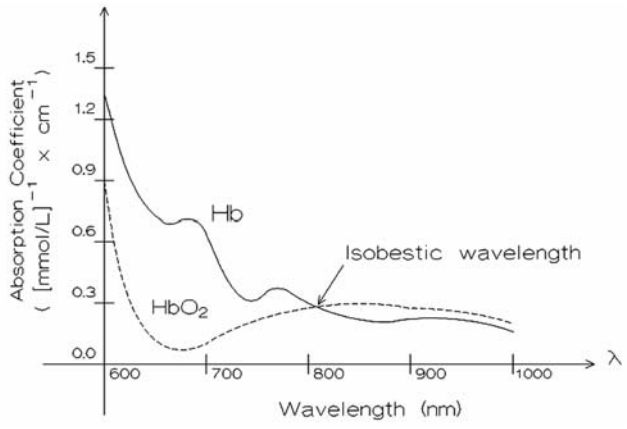

Figure 4-12. *Optical absorption spectra of oxygenated (HbO_2) and deoxygenated hemoglobin (Hb)*

Absorption of light as it passes through the tissue can be measured by shining a light onto the tissue and measuring the received light on the opposite site. If the wavelength of the incident light is known, then the absorption can be determined as:

$$\frac{I_R}{I_T} = e^{-acd} \qquad \text{Equation 1}$$

where:

- I_R is the intensity of the received light,

- I_T is the intensity of the transmitted light,
- a is the absorption coefficient,
- c is the concentration of the absorbing molecule (Hb or HBO_2)
- d is the thickness of the tissue.

The term $a.c.d$ is known as the optical density of the tissue, and expressed as:

$$OD = 1n \cdot \left(\frac{I_T}{I_R}\right) = acd$$ Equation 2

In the case of pulse oximetery, the optical density is determined at two wavelengths and the $Sp(O_2)$ is determined using the following relationship:

$$SpO_2 = A - B\frac{OD_{660nm}}{OD_{990nm}}$$ Equation 3

where the coefficients A and B must be determined experimentally.

Above described system is also able to detect the heart beats by sensing the changes in the blood volume following systole. As more blood enters the tissue after each beat, absorption characteristics of the tissue changes, which is reflected in the I_R.

Further Reading

You can find more information about pulse oximetry at:

- http://www.oximeter.org/

  This site contains a wealth of information on the history and principles of operation of pulse oximeters.

- http://engr.smu.edu/~cd/EE5340/lect30/index.htm

  This slideshow provides an in-depth look at the science of pulse oximetery.

Lab Meeting #4 Procedure

In this experiment we will use a portable pulse oximeter, Nonin Model 8600.

To Determine Your $Sp(O_2)$ Rate Using a Pulse Oximeter:

1. While the device is turned off, connect the finger sensor to the device using the break-out connector. Turn the device on.
2. Notice how the **Sensor** light is on but no $Sp(O_2)$ is displayed.
3. Place your finger into the sensor and wait until the pulse rate and $Sp(O_2)$ is displayed.

4. Take several readings of the astronauts. How do your pulse oximeter readings compare with your indirect colorimetry readings? Explain.
5. Take a shallow breath and hold your breath for at least 20 seconds. Monitor the changes in the heart rate and $Sp(O_2)$.
6. Using a the NI PXI soft scope application, observe the changes in the received signal strength. Is it synchronized to your heart rhythm?
7. Using your hand held digital oscilloscope, make four recordings of the received optical signals from the light sensor
   - No objects are in the sensor
   - Your finger is in the sensor
   - Pink filter is in the sensor
   - Green filter is in the sensor
8. Turn the pulse oximeter off.

Lab Report

Why do we need the reference measurement at $\lambda = 805$ nm or $\lambda = 910$ nm? Why can not we simply measure the absorption at $\lambda = 660$ nm to determine the $Sp(O_2)$?

How does the signal strength change after the heart beat? Does this received signal get stronger or weaker after the systole? Does the pulse oximeter need measurements at both wavelengths for heart rate measurements?

Fill in the table below:

	Signal 1 Strength	Signal 2 Strength
Empty		
Finger		
Pink Filter		
Green Filter		

Explain the observations for the table above. Why are the effects of different filters on received signal amplitudes different? Based on this, which signal is the representing the $\lambda = 660$ nm and which signal is representing $\lambda = 660$ nm.

Based on the observations above, rewrite equation 3 in terms of Signal 1 Strength and Signal 2 Strength.

Biopotentials

Bioelectric potentials (or biopotentials) are a result of electrochemical activity in *excitable cells*—components of nervous, muscular, or glandular tissue. Electrically, these cells exhibit a *resting* potential and, when appropriately stimulated, an *action* potential. Given adequate monitoring equipment, the engineer of today can record many forms of bioelectric phenomena with relative ease. These phenomena include the electrocardiogram (ECG), electroencephalogram (EEG), electroneurogram (ENG), electromyogram (EMG), and electroretinogram (ERG). In this section, you will build an electrocardiogram (ECG) circuit from the component level and use it to measure the biopotential signals generated by a human subject.

For a fascinating and informative history of the ECG, visit the ECG Library at:

http://www.ecglibrary.com/ecghist.html

SECTION CONTENTS

PREREQUISITES

As a prerequisite to this laboratory, you will need to complete the "Teach Yourself LabView in 6 Hours Tutorial" *before the first day of this lab*. This tutorial is available on the BME UG Laboratory web site under the menu item **Class Resources** at:

- http://www.engr.utexas.edu/bme/ugrad/UGLab/resources/labviewintro.html

See "LabView Resources" on page 5-8 for further LabView resources.

INTRODUCTION TO ELECTROCARDIOGRAPHY

An electrocardiogram (ECG, or sometimes referred to as EKG) is a graphic tracing of the variations in electrical potential detected at the body surface caused by the excitation and relaxation of the heart muscle. ECGs are often used to help diagnose specific cardiac anomalies, such as disturbances of heart rhythm and conduction.

All muscle contractions generate action potentials that can be measured in the laboratory. In our laboratory project, we will build an electrical circuit that will detect and amplify the muscular contractions of the Myocardium muscle (or heart muscle). Though our circuit will prove rudimentary to commercially available versions, our device will nevertheless be quite effective for our electrocardiography needs.

When the heart beats, a large number of excitable cells de-polarize simultaneously and cause a significant voltage (2 mV to 4 mV) to be present around the heart. This voltage, a biopotential, is relatively large, it propagates to the skin's surface, but by the time it reaches the epidermis, the signal has attenuated significantly. Still, the biopotential that exists on the surface of the skin is enough to drive our ECG circuit.

To analyze and measure the biopotential signal, we must convert the attenuated signal present on the epidermis into a scalable electrical signal that accurately represents the biopotential signal. This is referred to as *signal transduction*—to transfer a biological signal into an electrical one. By using low-impedance electrodes which offer little resistance to the signal as it travels from the skin to the electrode wires, we achieve biopotential signal transduction.

Signal Conditioning

The signal that is converted from a biopotential into a scaled electrical signal is very small, and as such is highly susceptible to electrical interference which can distort and falsify the signal. In order to acquire a usable signal that is not influenced by undesirable interference (or noise), we must build a circuit that collects and then grooms the desirable part of the biopotential signal while filtering out the undesirable elements (noise). In our laboratory, we will achieve this goal of developing a distinct and uncluttered signal by creating an ECG circuit that not only collects the scaled electrical signal (representing the biopotential signal present at the epidermis), but also:

- *amplifies* the signal and the noise
- *filters* out unwanted frequencies above and below the signal
- and *reduces noise* present with the desired signal

Figure 5-1 provides a simplified diagram of an ECG measurement device.

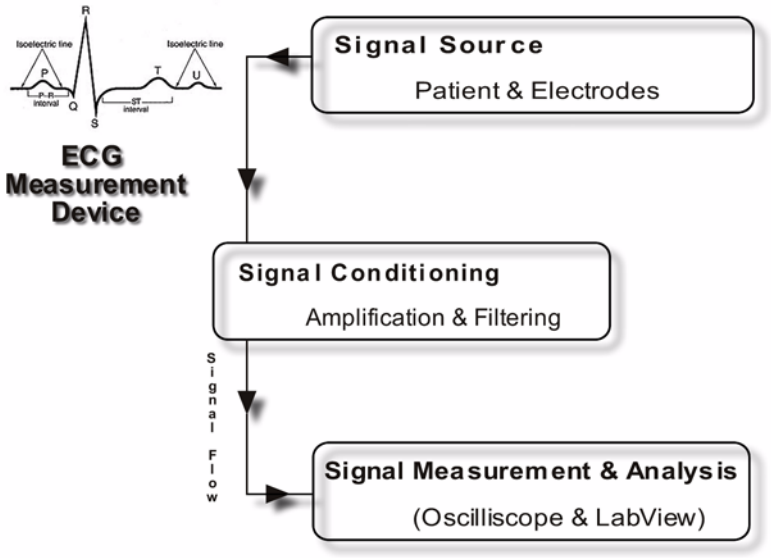

Figure 5-1. *Block diagram of an ECG measurement device*

Stages of the ECG Circuit

We will build our ECG circuit on prototyping boards which mount to the ELVIS stations in the laboratory. The ELVIS stations provide a variable power supply to the prototyping boards, as well as provide test points and a seamless interface with the laboratory computers and PXI test stands.For electrical safety, we will not use the ELVIS onboard variable power supply; rather, we will use batteries to power our circuit.

The ECG circuits that we will build up from the component level will contain three discrete stages: an amplification stage, a high-pass filter, and a low-pass filter. The amplification stage will boost the scaled electrical signal received from the electrodes situated on the skin. The filter sections will comb out the irrelevant frequencies, electrical noise, and other unwanted interference from the signal, leaving only the part of the converted biopotential signal that we wish to measure and record.

Figure 5-2 provides a schematic-view of the three stages of the ECG circuit we will build in our laboratory.

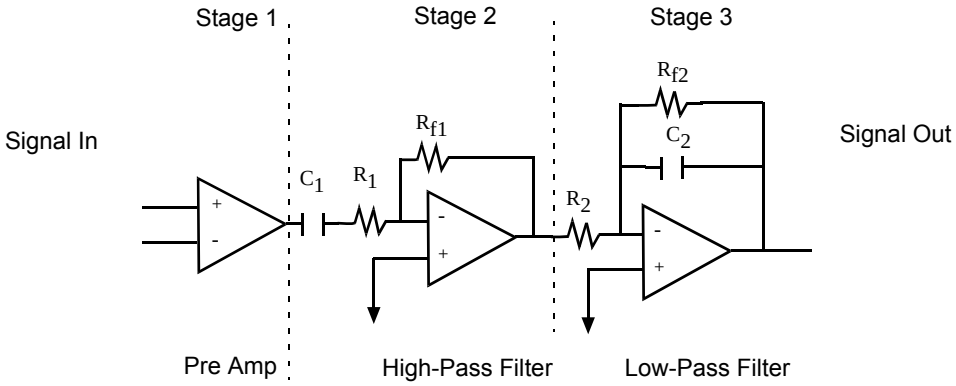

Figure 5-2. *Schematic diagram of the ECG circuit stages*

The following sections discuss the ECG circuit stages in more detail.

Stage 1: Amplification

Stage one is an instrumentation amplifier (AD620). The AD620 IC (integrated circuit) chip provides a high input impedance with low noise properties, and a large common-mode rejection ratio (CMRR). This is important to our circuit because the input to our amplifier section is an attenuated signal that is barely larger than the stray electrical signals and fields that exist in the laboratory. For instance, when standing in a typical room, there exists a *common mode voltage* on your body because of electrical fields created by power lines, florescent lights, and other sources of electricity. Additionally, any unshielded wires or leads can potentially become collectors or antennas of the common mode voltage.

The common mode voltage present on the epidermis of the subject is not a desired part of our signal, and if the input amplifier section does not immediately reject this stray voltage, the voltage will be with our signal. The high input impedance of the AD620 chip blocks current from travelling down from the amplifier to the electrodes. Unfortunately, this high impedance causes the leads from the electrodes to function like antennas, so we must shield them using coaxial cable.

The gain of the AD620 instrumentation amplifier can be set using the following equation:

$$G = 49.4\ k\ /\ R_g + 1$$

where R_g = value of the resistor you place across pins 1 and 8 (see Figure 5-11 on page 5-14 for an illustration of the AD620 pins)

A small gain of 3x to 10x will be sufficient for our process of amplifying the signal. We will calculate the value for R_g in “Connecting the AD620 Instrument Amplifier” on page 5-13.

Stage 2: High-Pass Filter

Stage two of our ECG circuit is an active high-pass filter. The configuration of this stage's components allows the filter to accomplish both gain and frequency selectivity. Signals relevant to the heart's biopotential occur between 0.05 Hz to 200 Hz. Our filter will allow all signals to pass through unaffected as long as they are above our selected *corner frequency* (in this case, 0.05 Hz). Since DC signals are solid-state signals and do not fluctuate at a frequency (an ideal DC signal has a frequency of 0.0 Hz), DC noise is filtered out of the signal at this stage.

The corner frequency is calculated as follows:

$$f_{corner} = 1 / (2*\pi*R_1*C_1)$$

In our circuit, the high pass filter stage we have gain (G) = 2.5 and f_{corner} = 0.05. The ratio of the feedback resistor to the input resistor equals the gain for both filter stages. As you can see, the capacitors have no effect on gain. By changing these values, you can easily change the dynamics of the circuit.

Stage 3: Lo-Pass Filter

Stage 3 of our ECG circuit is a low-pass filter. The low pass filter is very similar to the high-pass filter in operation. We can achieve gain, G, by setting the ratio of feedback resistance to input resistance. This time, the corner frequency is calculated as:

$$f_{corner} = 1 / (2*\pi*R_{f2}*C_2)$$

This is different from stage two in that the feedback resistance now dictates the frequency response. We have the corner set to 200 Hz. So now our signal will consist of components between 0.05 Hz and 200 Hz only. This is called the pass band. Figure 5-3 provides an illustration of our ECG circuit pass band.

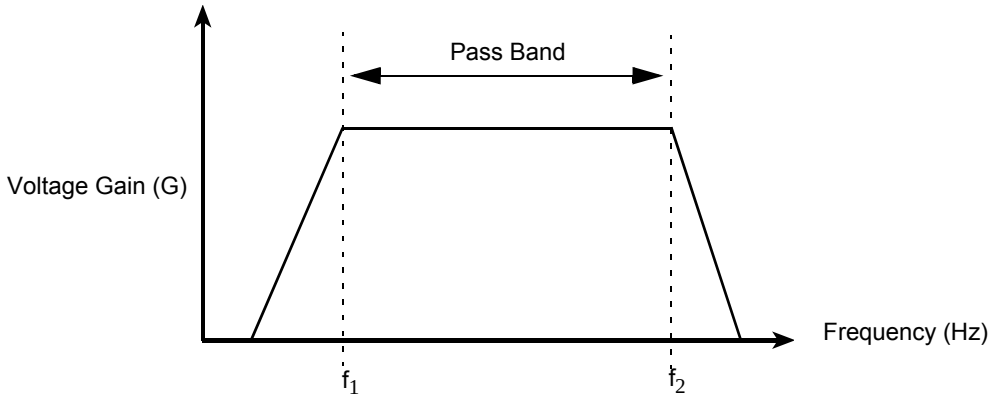

Figure 5-3. *Bode plot of the pass band*

The magnitude part of the *Bode Plot* (there is also a phase portion) describes what frequencies end up undergoing amplification. Notice the units on the axes. Also note that these relationships are linear. This linearity is ideal, and is not actually the case in practice.

Output Signal

Before we send our converted and cleaned-up biopotential signal to our measurement device, we pass the signal through a final amplification with a very high gain. The high gain significantly increases the amplitude of our signal, making it easily detectable and manageable. By placing high-gain amplification at the end of our signal chain, we are able to selectively increase our desired signal without amplifying noise because the majority of electrical interference has been filtered out by this point.

Once you have energized your circuit, it is important to monitor your ECG circuit output signal. The output must not go outside of the -9 to +9 range of your batteries. If your signal exceeds these specifications, it will become distorted, or saturated. This phenomena is referred to as *railing out* and is highly undesirable for electrocardiography applications.

Note: Frequently check the IC chips and your batteries for excessive heat. If you improperly bias your circuit, power will be dissipated inappropriately, and damage may result to your circuit components.

Summary

A summary of the equations that describe this circuit is:

$$G = G_1 * G_3 * G_3$$

where:

Stage 1	Stage 2	Stage 3
$G_1 = (49.4\ k\Omega / R_G) + 1$	$G_2 = (R_{f1} / R_1)$	$G_3 = (R_{f2} / R_2)$
$V_{out} = (G)(V_{in})$	$f_{corner} = 1/(2*\pi*R_1C_1)$	$f_{corner} = 1/(2*\pi*R_2C_2)$

Signal Measurement and Analysis

There are many aspects of the ECG signal that are relevant to physicians; however, in our laboratory, we will be primarily concerned with:

- **P-R time interval**—defined as the interval (or period) that extends from the onset of atrial depolarization (beginning of the P wave) until the onset of ventricular depolarization (beginning of the QRS interval). See Figure 5-4 for an illustration.
- Pulse frequency—defined as the beats per minute (bpm) of the heart
- Pulse frequency standard deviation

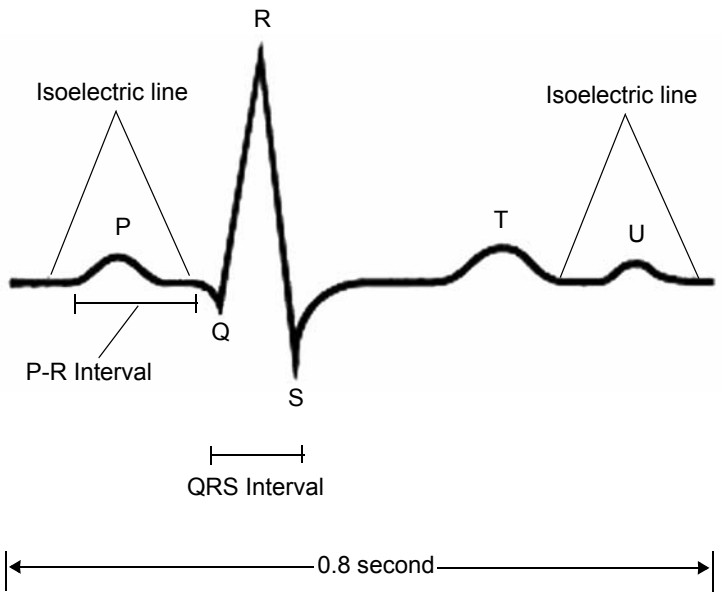

Figure 5-4. *Segment of a typical ECG signal*

Heartbeat Frequency

The time between heartbeats can be determined by measuring the distance between the maxima (point R in Figure 5-4) of two adjacent QRS intervals, you can find the time between two heart beats. If you divide this period into 60, you can calculate the pulse frequency; thus:

60 / (Period between two adjacent QRS intervals) = Pulse Frequency

Recent studies have suggested that it is *healthy* to have an *irregular* heartbeat. The cardiovascular system must constantly adapt to the effect outside stresses have upon our bodies. A consistent heartbeat would be perhaps ideal for resting and detrimental to walking. Even while sleeping, your heart is constantly adjusting to the requirements of the present. Knowing this, we can assume that a standard deviation of 0 ($\sigma = 0$) is a symptom of an unhealthy cardiovascular system (because it is not adjusting to the changing needs of the body).

LabView VIs (Virtual Instruments)

LabView is an application that allows you to create a custom interface for use with both software and hardware products. The custom graphical user interface (GUI) you create with LabView is called a VI, or virtual instrument. LabView programs are called virtual instruments because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. Virtual instruments are ideal for acquiring, analyzing, displaying, and storing data.

During this lab, you will modify and use two VIs: **ECG.vi** and **Analysis.vi**. These VIs are located on the laboratory share drive in the folder **LabView VIs**. To use these VIs, you will need to access this folder and copy the two files; then you will paste them locally to a folder on your own computer.

The VI **ECG.vi** counts each QRS interval peak as a beat, then takes the standard deviation (SD) of time intervals to find the SD of your heart rate. **ECG.vi** automatically makes these measurements for you. You will need to modify this VI by adjusting the threshold voltage for detecting a heart beat. The default value is 4 V. This means that as the QRS complex rises above 4 V, the VI will count a heart beat. So if any other part of your signal reaches this threshold, it will be counted as a beat. You will need to select a threshold voltage appropriate to the QRS interval you are measuring.

The VI **Analysis.vi** performs measurements on the ECG circuit output signal, and allows you to replay saved signals. In the share drive folder where you copied the Analysis.vi VI from is the folder **Examples**. In this folder you will find sample files that you may open with this VI and view. This will allow you to compare your gathered data to another signal.

Note: You may want to work on **Analysis.vi** or **ECG.vi** on a computer outside of the lab. To do this you will need to download the LabView application from the UT Engineering web site:

http://www.engr.utexas.edu/itg/ni.cfm

You will also need to download the Version 7.2 LabView palette functions from:

http://digital.ni.com/softlib.nsf/websearch/50F76C287F531AA786256E7500634BE3?OpenDocument&node=132060_US

LabView Resources

LabView is a complex application requiring a specific skill set that can only be acquired by study and practice. You will be required to have a firm grasp of the fundamentals of LabView to successfully complete this laboratory project. Therefore, you will need to complete the "Teach Yourself LabView in 6 Hours Tutorial" *before the first day of this lab*. This tutorial is available on the BME UG Laboratory web site under the menu item **Class Resources** at:

- http://www.engr.utexas.edu/bme/ugrad/UGLab/resources/labviewintro.html

Some other resources helpful in learning LabView are:

- http://www.ni.com/events/tutorials/campus.htm

  Interactive tutorials on LabView sponsored by National Instruments

- http://www.ni.com/labview/

  LabView links and information from National Instruments

PROGRESS AND LAB REPORTS

For due dates of assigned BME 221 laboratory writings, refer to the BME UG Lab web site at:

http://www.engr.utexas.edu/bme/ugrad/UGLab/calendar_221.html

Progress Report

A progress report—in the form of a technical memo—will be prepared individually by each person performing the experiment. The progress reports will be graded will be graded and returned to you by the last lab session of each experiment, so that you may use the reports in preparing for the final lab report.

The progress report should be written after two lab sessions (halfway through the lab). The reports are then due at the beginning of the third lab session. See the specific instructions on technical memos beginning at “Technical Memos” on page 6-9.

Lab Report

In the lab report, it is expected that all the details of building an ECG circuit and a LabView soft panel will be described to a level where the work may be duplicated by a reader of the report. A full description of all experimental procedures will also be presented. The results and discussion sections will present and discuss the results of the studies. The effect of caffeine and/or sugar upon the readings should be discussed. A comparison between your readings and the readings provided is expected.

LAB MEETING #1

During this lab we will build an ECG circuit containing three discrete stages, a pre-amplification stage (built around an AD620 IC chip), an active high pass filter, and an active low pass filter (both filter stages are built around separate OP07 IC chips). If you desire to learn more about these integrated circuit components, specifications sheets can be accessed via the internet:

- http://www.analog.com/UploadedFiles/Data_Sheets/37793330023930AD620_e.pdf

  and

- http://web.mit.edu/6.301/www/OP07_a.pdf

Copies of these specifications can also be copied from the share drive from the **Specifications** folder. The files are titled **AD620specs** and **OP07specs**.

Circuit Schematic

Figure 5-5 provides a schematic outline of the circuit you will build during this lab.

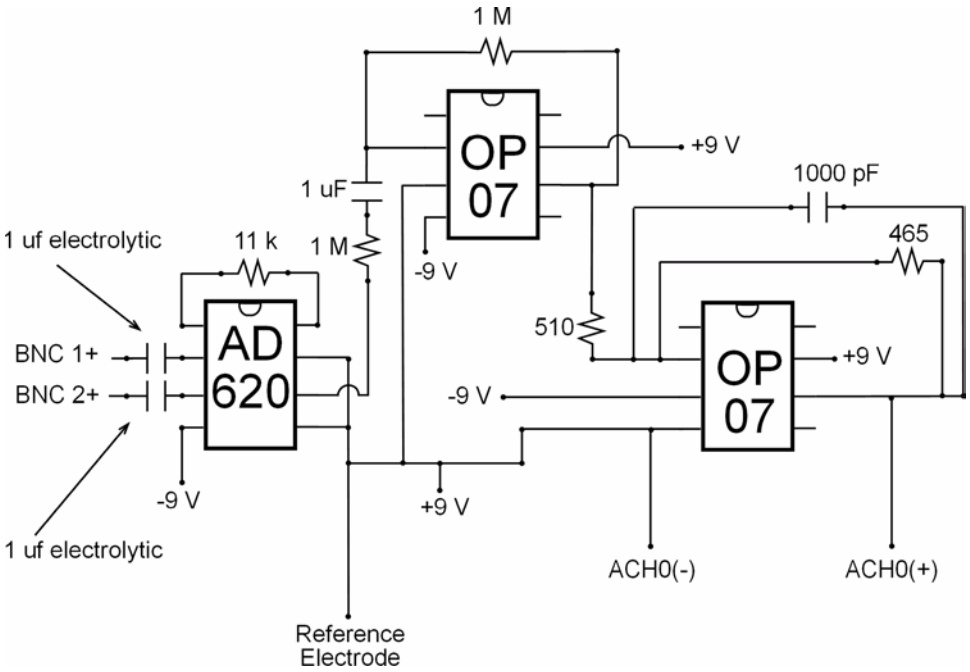

Figure 5-5. *Schematic diagram of the ECG circuit*

Parts List

To build the ECG circuit, you will require the following components (the number in parentheses following the component is the number required):

- AD620 Amplifier (1)
- OP07 Op Amp (2)
- 1 uF 50 V electrolytic capacitor (2)
- 1 uF big red capacitor (1)
- 1000 pF ceramic capacitor (1)
- 11 kohm resistor (1)
- 1 Mohm resistor (2)
- 510 ohm resistor (1)
- 465 kohm resistor (1)

Lab Meeting #1 Procedure

Start building your ECG circuit by placing your three IC chips on the prototyping board. Space the chips out to make room for other components and connections. Figure 5-7 demonstrates an op-amp placed on the prototyping board so that each of the eight terminals of the chip are isolated from one another.

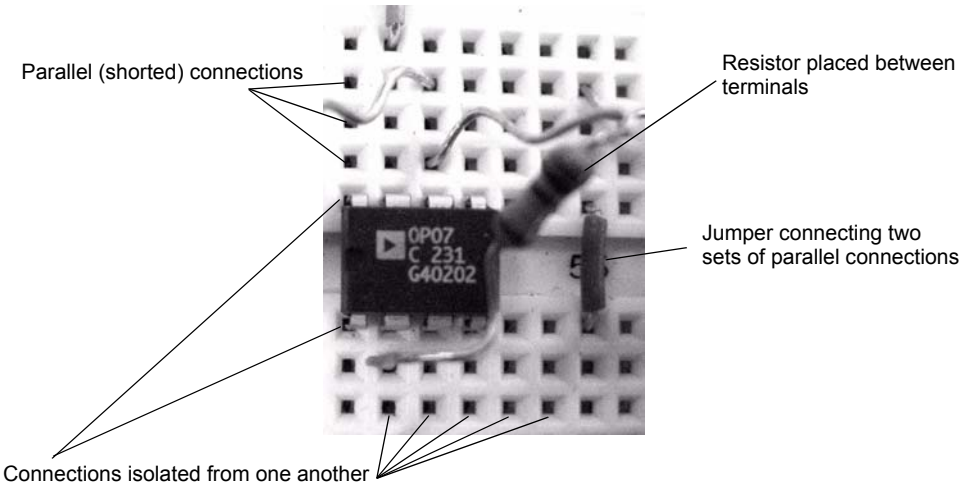

Figure 5-6. *Example of an op-amp seated correctly on a prototyping board*

Connecting the Power Supply Leads

The ECG circuit requires two constant voltage potentials: +9 VDC and -9 VDC, as well as ground. The ELVIS station will provide a ground connection (see Figure 5-7). We will use two 9-V alkaline batteries to provide our voltage potentials.

Note: You can damage your circuit if you exceed the ±9 VDC required by the circuit. Always ensure that your connection polarities are correct.

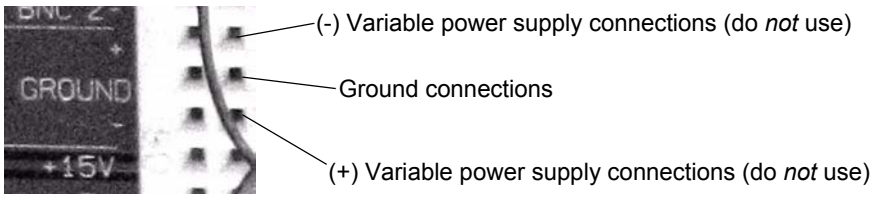

Figure 5-7. *Ground connections on the prototyping board*

To Make Power Connection for the ECG Circuit:

Before connecting the power supply leads, you will want to ensure that your batteries are fully charged. Using a multimeter, measure the voltage across the battery terminals. Your battery must read 9 VDC ± 1.5 VDC.

1. Ensure the ELVIS workstation is de-energized.
2. Using the provided jumper wire, connect pin 4 of both OP07 chips and the AD620 chip to the -9 VDC terminals of your batteries (see Figure 5-11 and Figure 5-12 for an illustration of the IC chip pins).
3. Using the provided jumper wire, connect pin 7 of both OP07 chips and the AD620 chip to the +9 VDC terminals of your batteries.
4. Using the provided jumper wire, connect pin 3 of one OP07 chip to the **Ground** connection (see Figure 5-5 on page 5-10 for further information).
5. Using the provided jumper wire, connect pin 5 of the AD620 chip to the **Ground** connection.

A good habit to develop is to create voltage busses when you will be making several connections to a power supply or ground. For instance, our ECG circuit requires several connections to ground on the prototyping board, so you may choose to create a ground bus to facilitate the multiple connection points. This also will ensure that your ground potential is constant and does not float.

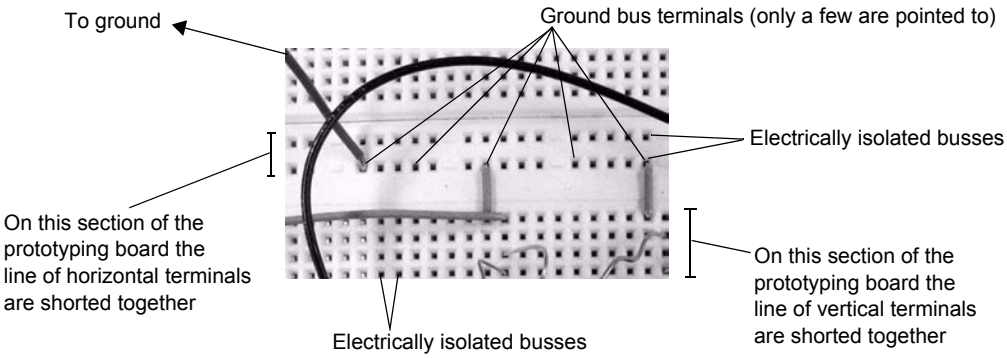

Figure 5-8. *Examples of prototyping board busses*

Connecting the AD620 Instrument Amplifier

We will collect our biopotential signal using two standard Ag/AgCl electrodes commonly used in the medical profession for such purposes. We will couple the attenuated signal from the electrodes to the first stage of our ECG circuit using two shielded coaxial leads (RG-58 wire) with BNC connectors on one end which connect with the BNC connectors on the prototyping board. The other end of the shielded coaxial cable is equipped with alligator connectors which clamp to the output terminal of the electrodes.

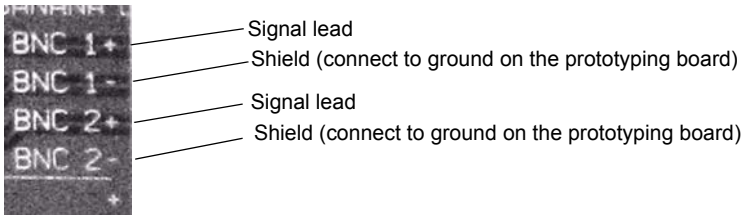

Figure 5-9. *BNC input connections on prototyping board*

In an attempt to reduce line-level DC voltages present on the leads between the biopotential sensors (the Ag/AgCl electrodes) and the biopotential signal amplifier (AD620 chip), we will place electrolytic capacitors between the electrodes and the amplifier. The capacitors block DC signals and pass AC signals. The large capacitance value of our capacitors (1.0 µf) allows the capacitor to pass very low frequencies while filtering DC signals.

The most important characteristic of electrolytic capacitors is that they have a positive and a negative electrode. If the capacitor is subjected to voltage exceeding its working voltage, or if it is connected with incorrect polarity, it may burst. It is extremely dangerous, because it can quite literally explode.

Electrolytic capacitors generally have markings indicating their polarity. In Figure 5-10, the arrows on the capacitor housing point toward a "–" sign and the end of the capacitor that must be kept more negative. Ensure that you have correctly identified the polarity of your capacitors before connecting them.

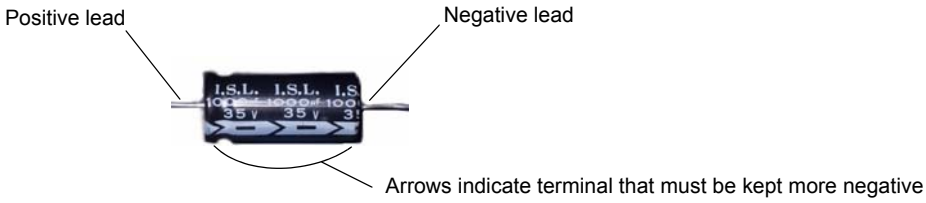

Figure 5-10. *Polarity of an electrolytic capacitor*

⚠ CAUTION:

Explosion Hazard. Electrolytic capacitors may burst if connected incorrectly. Observe the polarity of the capacitors and wear safety glasses at all times when working around electrolytic capacitors.

To Connect the AD620 Instrument Amplifier:

Note: Cut your circuit wires and component leads as short as possible to reduce electrical noise.

1. Connect the positive (+) lead of a 1 µF electrolytic capacitor to the **BNC 1+** terminal on the prototyping board; connect the negative (-) lead to pin 2 on the AD620 chip.

   Note: You may substitute a 0.1 µF to 1 µF electrolytic capacitor, if necessary. The purpose of this capacitor between the electrode and instrument amplifier is to reduce line-level DC voltage travelling with the converted biopotential signal.

2. Connect the positive (+) lead of a 1 µF electrolytic capacitor to the **BNC 2+** terminal on the prototyping board; connect the negative (-) lead to pin 3 on the AD620 chip.
3. The AD620 instrument amplifier requires an external resistor (R_g) placed across pins 1 and 8 to set the amplifier's gain. Calculate the value of the resistor necessary to provide a 3x to 8x gain. See "Stage 1: Amplification" on page 5-4 for information relevant in making this calculation.
4. Connect R_g between pins 1 and 8 of the AD620 chip.

Figure 5-11 provides an illustration of the AD620 instrument amplifier pins.

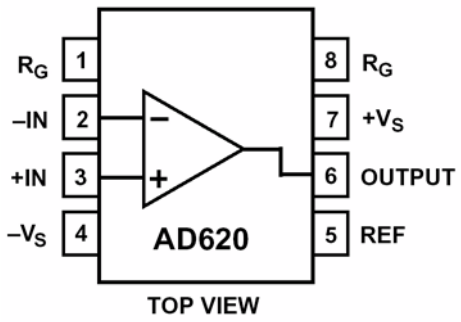

Figure 5-11. *AD620 instrument amplifier pin connections*

Connecting the High-Pass Filter

Next we must connect the output from the pre-amplification stage (AD620 instrument amplifier) to the high-pass filter stage. Figure 5-11 shows that the AD620 output is pin 6. Figure 5-12 shows that the OP07 chip, the core of the high-pass filter circuit, has two inputs:

- Pin 2—the negative input (-)
- Pin 3—the positive input (+)

Use the schematic diagram of our ECG circuit (Figure 5-2 on page 5-4), to determine which OP07 input pin should be connected to ground, and which pin should be connected to the output of the first stage.

To Connect the High-Pass Filter Stage:

1. Place one lead of R_1 (1.0 MΩ resistor) in contact with pin 6 of the AD620 chip.

   Place one lead of C_1 (1.0 µF capacitor) in contact with the high-pass filter OP07 pin 2.

2. Place R_1 (1.0 MΩ) and C_1 (1.0 µF) in series on the prototyping board.
3. Place a 1.0 MΩ feedback resistor (R_{f1}) between pins 2 and 6 of the high-pass filter OP07.

Figure 5-12 provides an illustration of the OP07 op-amp pins. Notice op-amps have either a notch or small bubble on one end to help you identify the pins.

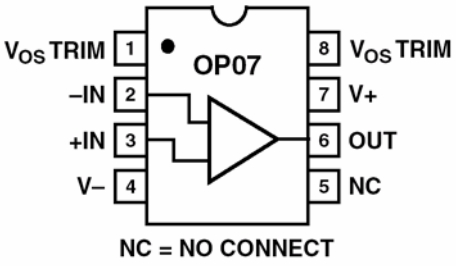

Figure 5-12. *OP07 connections*

Low Pass Filter Set-Up

The low-pass filter is built around an OP07 op-amp chip. Pins 2 and 3 are the input connections for the op-amp. Use the schematic diagram of our ECG circuit (Figure 5-2 on page 5-4), to determine which OP07 input pin should be connected to ground, and which pin should be connected to the output of the high-pass filter.

To Connect the Low-Pass Filter Stage:

1. Couple the output of the high-pass filter stage (pin 6) to pin 2 of the low-pass filter OP07 chip using R_2 (510 Ω resistor).

2. Connect R_{f2} (510 kΩ feedback resistor) across pin 2 and pin 6 of the low-pass filter OP07 chip.
3. Connect C_{f2} (1000 pF feedback capacitor) across pin 2 and pin 6.

Connecting the ECG Circuit Output

Once we have detected the biopotential signal, converted it into a scaled electrical signal, and pushed it through our ECG circuit to amplify and filter it, we are ready to input this signal into an instrument that can graphically display the signal we are interested in. Oscilloscopes and digital multimeters are common examples of hardware instruments used for measuring and displaying signal information. In our lab, we will use virtual instruments hosted on our lab computers. Virtual instruments have many advantages over hardware instruments in that they are almost unlimited in their potential. Depending on the processing power of your computer, you can create virtual instruments that can achieve measurements unimaginable in a hardware counterpart. Additionally, since the virtual instruments are software products, they present significant benefits over hardware products when space is at a premium.

In our lab, directing the output of our ECG circuit is relatively easy. The prototyping board and ELVIS station are integrated with our lab computers using a DAQ (data acquisition card) installed in the desktop computer and connected to the ELVIS station.

To Route the ECG Circuit Output to a Connected Lab Computer:

1. Connect the output of the low-pass filter stage (pin 6 on the OP07 chip) to **ACH0+** on the prototyping board.
2. Connect **ACH0-** on the prototyping board to the ground bus.

Figure 5-13 shows a prototyping board configured to output an analog signal to the DAQ board inputs **ACH0+** and **ACH0-**.

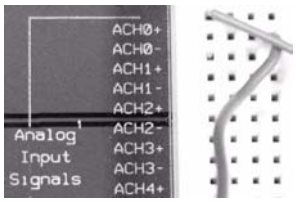

Figure 5-13. *DAQ interface input connections on prototyping board*

Checking Your Work

When you have completed creating your ECG circuit, you will want to check your wiring. It is relatively easy to cross a connection, and when dealing with sensitive electronic components, such a mistake can damage your circuit permanently.

Using the circuit schematic (Figure 5-2 on page 5-4) and a Fluke 175 multimeter (set to read ohms), check the signal flow of your circuit thoroughly to ensure that pins, leads, and components that are supposed to be shorted together are indeed shorted together, and that pins, leads, and components that should be isolated from one another are isolated.

Summary

By the conclusion of the first meeting of this lab you should have created a ECG circuit on your prototyping board. You should remove your prototyping board and store it in your group's assigned locking drawer.

If you did not finish constructing your circuit, you can take the prototyping board with you and finish outside of class. The prototyping boards are fairly expensive, and you will be held responsible for the safe return of these boards at the end of class, so ensure that you keep the boards safe and handle them with caution.

LAB MEETING #2

During this lab meeting, you will create a virtual instrument to collect signals from the ECG circuit you built and tested during the previous lab meeting. You will create the virtual instrument using LabView. To do this, you will need to have a familiarity with the application. "LabView VIs (Virtual Instruments)" on page 5-7 provides a brief introduction to LabView and lists some tutorial resources.

Prelab Assignment

Before arriving in lab, complete the "Teach Yourself LabView in 6 Hours" interactive course posted at:

http://www.engr.utexas.edu/bme/ugrad/UGLab/resources.html

Lab Meeting #2 Procedure

To create the virtual instruments necessary to measure, display, analyze, and record the converted biopotential signal from the ECG electrodes, you will need LabView. The laboratory computers are equipped with this application. You may access the application by selecting: **Start** > **Programs** > **National Instruments** > **LabView**.

Note: National Instruments (NI) provides free access to most of its software products to University of Texas at Austin Engineering students. Visit http://www.engr.utexas.edu/itg/ni.cfm to download a copy of LabView to your personal computer if you wish to work on your virtual instruments outside of the laboratory.

There are two VIs (virtual instruments) associated with this laboratory project: **ECG.vi** and **Signal Analysis.vi**. We will create and use **ECG.vi** to acquire your biopotential signal, display it onto a waveform chart, and write the data to file.

The second VI is **Signal Analysis.vi**, which reads *.lvm* files—a file type generated when data is saved with the **ECG.vi**. This VI displays the file selected and performs measurements such as most recent pulse, pulse average, number of beats, and standard deviation.

Note: For the next lab meeting, do not consume any caffeine or sugar-intensive beverages. We will be taking resting ECG readings and do not want to you to have an irregular heartbeat due to the effects of caffeine or sugar.

For the fourth lab meeting, you will be allowed to consume caffeinated beverages to compare readings with the readings from the third lab.

Creating the ECG Virtual Instrument

To Create the ECG Virtual Instrument:

1. Open LabView.
2. If you an expert user of LabView, open a blank VI and assemble the VI as shown in Figure 5-14.
3. If you are not an expert user of LabView, navigate to the **ECGstart.vi** and open this file. This VI is located in the **Z Drive: Library** in the following path: **Biopotentials** > **LabView Programs**.
   a. With the file open, select **Window** > **Show Block Diagram** (or press **Ctrl** + **E).** You should see a collection of LabView functions and sub-VIs with block captions describing them generally.
   b. Ensure the **Context Help** window is open. Place your cursor over a function or sub-VI on the screen. The **Context Help** window provides information about the item you have selected.

   Note: To open the **Context Help** window, select **Help** > **Context Help** (or press **Ctrl** + **H**).

   c. Assemble your VI as shown in Figure 5-14. When you are finished, save your file locally as **[your section number]ECG.vi**. For example, laboratory section 1 groups will save their VI locally as **1ECG.vi**.

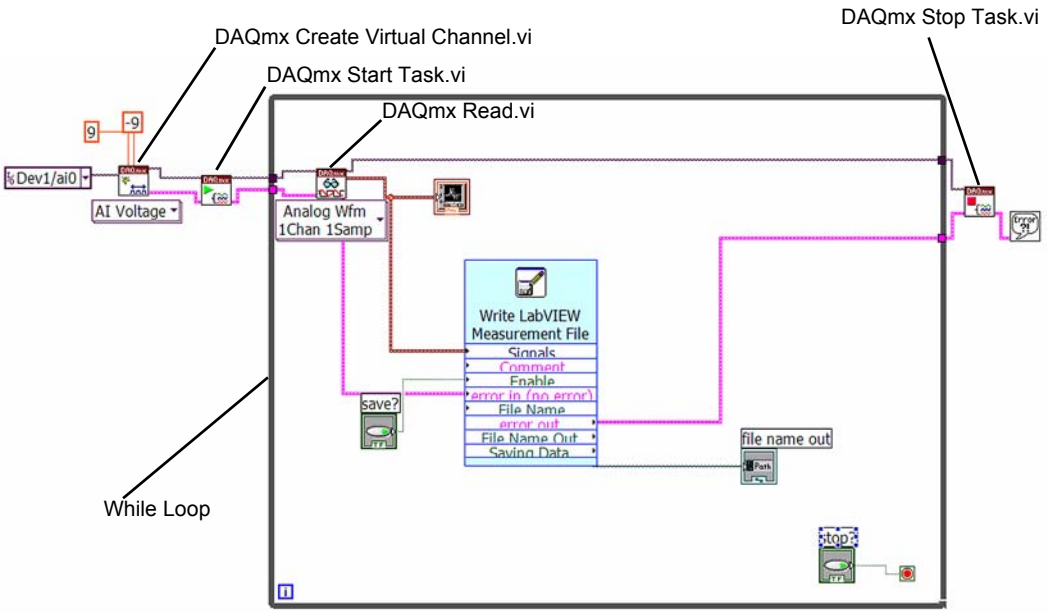

Figure 5-14. *Block diagram of ECG.vi*

Creating the Signal Analysis Virtual Instrument

To Create the Signal Analysis Virtual Instrument:

1. Open LabView.
2. If you an expert user of LabView, open a blank VI and assemble the VI as shown in Figure 5-15.
3. If you are not an expert user of LabView, navigate to **Analysis_start.vi** and open this file. This VI is located in the **Z Drive: Library** in the following path: **Biopotentials** > **LabView Programs**.
   a. With the file open, select **Window** > **Show Block Diagram** (or press **Ctrl** + **E).** You should see a collection of LabView functions and sub-VIs with block captions describing them generally.
   b. Ensure the **Context Help** window is open. Place your cursor over a function or sub-VI on the screen. The **Context Help** window provides information about the item you have selected.

   Note: To open the **Context Help** window, select **Help** > **Context Help** (or press **Ctrl** + **H**).

   c. Assemble your VI as shown in Figure 5-15. When you are finished, save your file locally as **[your section number]Analysis.vi**. For example, laboratory section 1 groups will save their VI locally as **1Analysis.vi**.

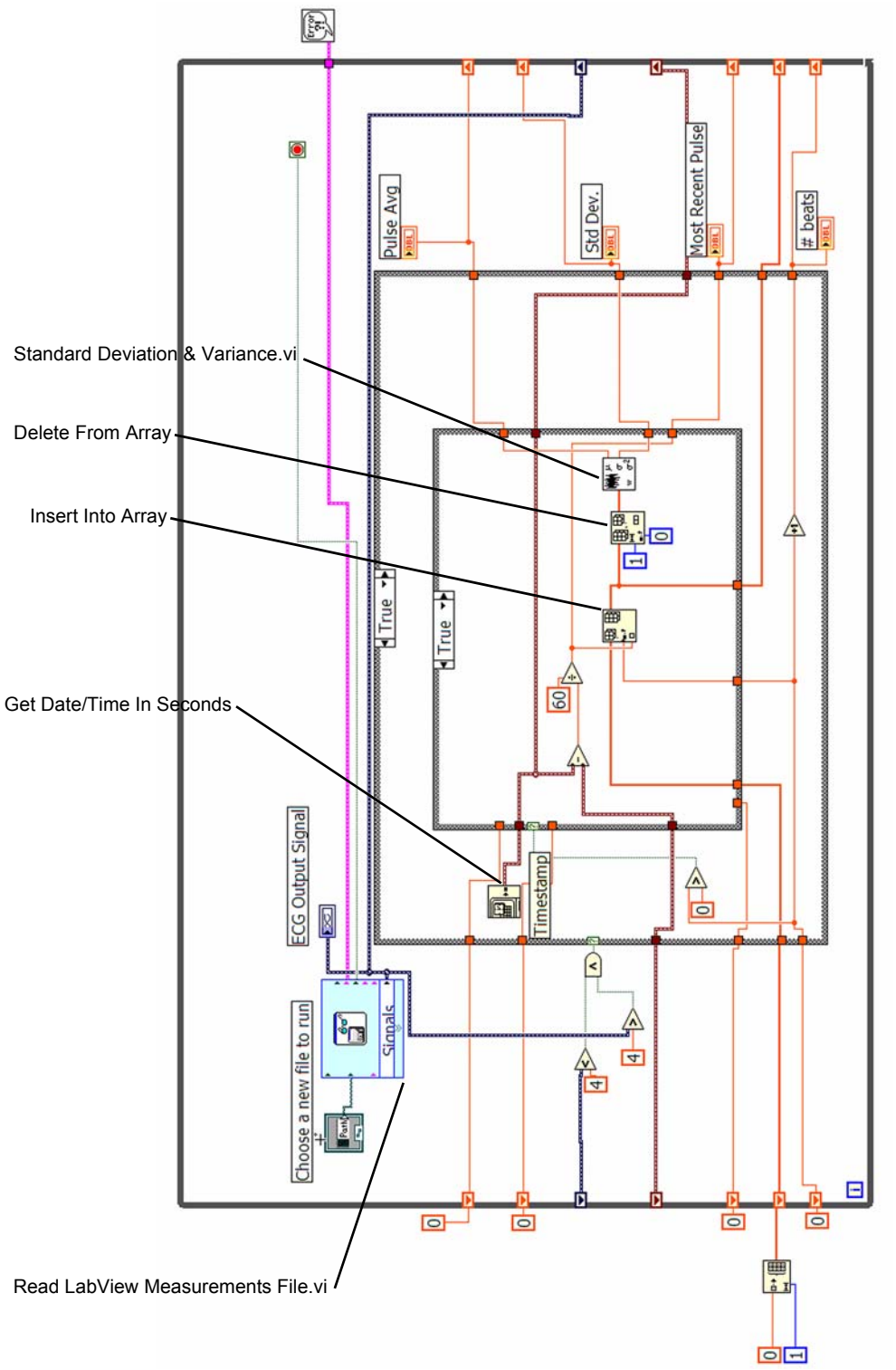

Figure 5-15. *Block diagram of Signal Analysis virtual instrument*

The ECG.vi

On the front panel, if the save button reads **Save**, then you are currently saving data to the file indicated. If it reads **Stop**, then you are viewing the data real-time, but you are *not* saving data.

Note: If your ECG signal looks cut off, stop the VI. Right-click the chart, go to **Y-scale**, then **formatting**. Next, click on the **scales** tab and select a more appropriate range for your chart. Usually, you will want to select **auto-scale**.

The Analysis.vi

The front panel displays which file is being read. If you wish to read from a different file, simply type it into the **Choose a new file to run** field. It also performs measurements such as most recent pulse (this measures your pulse in beats per minute (bpm) assuming you heart pumps at that constant rhythm for the rest of the minute), pulse average, number of beats, and standard deviation.

Note: If you pause the VI, you cannot continue and achieve accurate data. If you feel the need the pause the VI, please stop execution, before restarting.

Please refer to the block diagram for information on how the VI works. There are two case statements. The first case checks to see if a heartbeat has taken place (if voltage > 4 V). Please feel free to change this constant if your T-waves exceed this value. Otherwise, the vi will interpret T-waves as QRS complexes. The inside case checks if there are at least 2 elements in the analysis array (that is, if at least 2 beats have gone by). With only one beat gone by, you cannot obtain data.

Note: You will notice if you repeatedly read from the same ECG file, you will not obtain identical values for pulse average, and so on. This is because the VI reads absolute time and slight computation time differences will cause your values to change ever so slightly. Please see the attached pages for both VIs.

Questions to Think About

At this point you have successfully constructed virtual instruments to capture and analyze your ECG signal. It is important that you understand how the VIs work. Take a few moments, and write down answers to the following:

- What do each of the sub VIs in Figure 5-14 on page 5-19 and Figure 5-15 on page 5-20 do? How are they important to the VI? What specific functions do they serve?
- The Analysis VI (Figure 5-15 on page 5-20) is rather complex at first blush, but we can divide the VI into three major sections. What are these sections? What does each section do?
- What exactly does the Analysis VI calculate? Using the VI (Figure 5-15 on page 5-20) itself, produce the equation that represents what the VI is doing.

LAB MEETING #3

During this lab you will connect your ECG circuit to a LabView VI (virtual instrument) to measure and record various outputs from the ECG while connected to a human subject.

Lab Meeting #3 Procedure

During this portion of the lab, you will use Ag/AgCl electrodes. These electrodes should not be shared among group members. When you are finished using the electrodes during this lab, label and store your electrodes so that you may use them for the next lab as well.

Note: During this lab meeting, you should have not consumed any caffeine beverages (that may cause irregularities in your heartbeat).

To Collect ECG Readings:

1. Locate the Ag/AgCl electrodes for use with your ECG circuit. Each member of the group will require 3 electrodes. Do not use any more than 3 electrodes per person.
2. Energize your ELVIS station.
3. Ensure that your batteries are connected and charged within specifications. See "Connecting the Power Supply Leads" on page 5-11 for power specifications.
4. Each group member should place their ECG electrodes where they believe they will get the best reading.
5. Take a reading from each group member while resting. Rearrange the electrodes as necessary to get the best reading. Save each of the readings for later analysis.
6. During one member's readings, disconnect the right leg ground. You should see the noise increase. Why does this happen?
7. Remove your electrodes and replace them to the storage surface. Label the electrodes with the member's name. Place the electrodes in your locking drawer for use during the next laboratory session.
8. Using **Analysis.vi**, analyze the collected ECG signals. Contrast and compare the readings. Highlight anything interesting that you find. Postulate reasons for similarities and differences that you might discover.

LAB MEETING #4

During this lab you will take ECG readings on human subjects that have consumed caffeinated or sugar-intensive beverages. You will compare these new readings with readings taken from the previous lab. You will also collect readings after a subject has

performed moderate exercise for 5 minutes. Again, you will compare these readings with readings from the previous lab. Finally, you will be provided some unidentified ECG readings to compare to your readings and speculate on their origins and the conditions the readings might have been taken under.

Students with any health (or other) concerns should not participate in any of the laboratory exercises that may endanger their health or violate their personal beliefs.

Lab Meeting #4 Procedure

To Collect ECG Readings:

1. Locate the Ag/AgCl electrodes for use with your ECG circuit. Each member of the group will require 3 electrodes. Do not use any more than 3 electrodes per person.
2. Ensure that your batteries are connected and charged within specifications. See "Connecting the Power Supply Leads" on page 5-11 for power specifications.
3. Each group member should place their ECG electrodes where they believe they will get the best reading.
4. Take readings of group members who have consumed caffeine or sugar-intensive beverages. Save each of the readings for later analysis.
5. Take readings of group members who have performed moderate physical exertion for 5 minutes. Save each of the readings for later analysis.
6. Remove your electrodes and discard them in an appropriate receptacle.
7. Using **Analysis.vi**, analyze the collected ECG signals. Contrast and compare the readings. Highlight anything interesting that you find. Postulate the reasons for similarities and differences that you might discover.
8. Analyze some of the unidentified ECG samples. Contrast and compare the readings with your own collection. Highlight anything interesting that you find. Postulate the reasons for similarities and differences that you might discover.

Appendix

This section contains information about the various forms of scientific writing you will be required to use in BME 221, as well as the rubrics that will be used by your instructor and TAs to evaluate your writing assignments.

SECTION CONTENTS

ACADEMIC INTEGRITY

The University has a strict policy on academic integrity. Any form of plagiarism or academic dishonesty will NOT be tolerated in BME 221. If you have any questions, please consult the web sites below:

- http://www.utexas.edu/depts/dos/sjs/academicintegrity.html
- http://www.utexas.edu/courses/clubmed/plgrism_cit.html

Failure to comply with the University's policy will result in a "zero" in the assignment and an "F" for BME 221.

FORMS OF SCIENTIFIC WRITING

The following sections provide a brief outline of the types of scientific writing you will be required to use in BME 221.

Laboratory Notebooks

Your laboratory notebook is the primary repository for the data you collect this semester. It is therefore important that you adhere to proper note-keeping standards. All entries in your laboratory notebook must be clear and complete; it should contain sufficient information that your teams and your TA can read and understand without any difficulty. See example in Appendix B.

Please pay particular attention to the following points when recording data in your laboratory notebooks:

1. Always use a ballpoint pen and never a pencil when making entries in your lab notebook. You and your team members are responsible for safeguarding your laboratory Black is best, but blue is also acceptable.
2. At the end of a lab session, all the team members should witness and sign the laboratory notebook. Your TA should also witness and sign your laboratory notebook when the entry is complete.
3. Since you will need to have your notebooks with you outside of the lab period (for preparing technical memos, reports and presentations), the notebooks will not be stored in the lab drawers.
4. Under no circumstances should any data be recorded on scraps of paper, backs or palms of hands, shoe soles, etc. Always enter the data in the notebook as the data is being collected.
5. Reserve the first two pages of your laboratory notebook for a table of contents. These pages should be updated periodically. Before starting each experiment, you should have a plan for the day's work (Pre-lab write-up). This plan should already be outlined in your notebook. Your TA will grade your pre-lab write-up before

you begin the experiment.

Note: The Pre-lab write up should be done by the student who will be writing the final lab report.

The pre-lab write-up should include a general overview of objectives. It should also contain relevant experimental procedures, any unusual safety protocols, and expected/predicted outcomes. In addition to raw data that are collected during the experiment, your laboratory notebook should also contain records of data analysis. While it is not necessary to transcribe information such as equation derivations in your notebook, you should write down the final equation that is used and reference the source. Graphs and figures that result from data analysis should be pasted in your notebook. You should also include a brief discussion that explains the data analysis portion of your records.

Your TA will review the contents of your laboratory notebook each week and provide constructive criticisms. Analyze your data as you conduct your experiment. Do not wait until you have collected [what you think] is all the data before doing so. You may run out of time by the end of the day before you decide that you need to collect some crucial data.

For more information on laboratory note-recording, please refer to:

"Writing the Laboratory Notebook," by Howard M. Kanare (Washington DC: America Chemical Society, 1985). The most relevant sections are pp. 1-8, 14-16, 40-41, 44-45, 53-79, 81-93, and 126-127.

Some additional bits of advice (or reinforcement) are provided below:

1. *The laboratory notebook should be a readable document, not merely a logbook in which numbers are recorded.* Your records must contain everything necessary for someone else to read and fully understand the experiment – it should contain an overview of the experiment, a brief description of the apparatus, all your collected data, an outline of the data analysis (and principal findings), and major conclusions. Your notebooks should be up-to-date at all times: always write down what you are doing or thinking AT THAT TIME, not later. "Pasted-in" items should be limited to data traces acquired by computer or graphs and figures produced by spreadsheets. You should NOT paste in sections of text.
2. *Record your analysis in your notebook.* For example, if you are fitting your data to some theoretical model, your notebook should contain the equations describing the model (do not forget to cite the source from which the equation was taken), the parameters obtained from the fit, and a graph showing the fit superimposed on the data. Although the data fitting itself is done on a spreadsheet, it is essential that you record the method of analysis and the principal findings in your laboratory notebook as they are obtained.
3. *Always try to quantify errors at the time of measurement.* Your error analysis will require you to identify possible sources or error, as well as estimate their magnitudes.

4. *Record your visual observations.* What color is the solution? Is your mixture boiling at a specific temperature? Also record changes in observations.
5. *Properly annotate errors.* You realize that the calculations on page 17 of your laboratory notebook (which was done earlier during the experiment) are incorrect and you are currently up to page 25. You should draw a single line through the erroneous section on p. 17, add a note in the margin that these calculations are incorrect and that the correct version is on p. 25. You should then date and initial the note.
6. *Table of Contents.* The purpose of the table of contents is to help a reader find the page he or she is looking for. Consequently, the entries in the table should be sufficiently descriptive and numerous that a reader can easily identify the proper section and go directly to the point of interest. A subheader such as "Data Analysis" under "Experiment 1" does not provide sufficient information. Instead, try "Data Analysis: Estimating Stage Efficiencies".
7. *Use your laboratory notebook.* Proper note taking in your laboratory notebook will help you prepare your reports. Use it to your advantage. Do not do the reverse – do not paste your conclusions from your technical memo or your conclusions slide from your laboratory notebook. That is *not* what the laboratory notebook is meant for.

Long Report

Each of the three standard experiments will result in a long report assignment. Keep in mind that this is a *group* project. I would like you to write up your results in a manuscript format, suitable for publication as a Research Article following the format of *Biomaterials*. Manuscript writing is an important skill to have, especially if you are going to graduate school, but also if you join industry. Be sure to give sufficient background information so a reader with a science background, but not necessarily an expert in the field, can understand your manuscript. Article from *Biomaterials* have been uploaded to the BME UG Lab web site as examples (http://www.engr.utexas.edu/bme/ugrad/UGLab/resources.html).

The following sections describing the long report have been reproduced from the *Biomaterials* web site [https://www.editorialmanager.com/biomat/]. I'd like for you to abide by these closely.

Manuscript Style and Length

The following sequence is normally required: title, authors, affiliations, abstract, keywords, introduction, materials and methods, results, discussion, conclusions, acknowledgements, appendix (where necessary), figure captions, and tables. The paper should be no more than 10 pages and should be double-spaced.

The Title

The title is obviously the major factor that determines who will find and read the paper and great care should be taken with it. The title should be sufficiently informative so that the reader can immediately assess its likely relevance, but without being excessively long. The title does not have to convey the results or the conclusion, nor indeed does it have to specify the techniques used unless it is a technique—oriented paper. It is best to avoid sentences as titles; the best titles have between six and twelve words with no verbs.

The Authors

Each paper should have a corresponding author, and the affiliations of all authors should *not* be ambiguously stated.

Keywords

Keywords have become very important with respect to literature searches and many search engines operate through the listing of these words. It is in the author's interest to think carefully about the words that will attract interested readers to their paper. There is little point in using very generic terms such as biomaterial, implant, drug, tissue engineering and prosthesis as key words. Equally there is no point in using obscure names, and it is best to avoid the author's own abbreviations.

The Abstract

Next to the title, the abstract will be the second most important point of entry to the paper since most search facilities will print the abstract as part of the service, and far more people will read the abstract than the full papers. The abstract should be concise and informative. It is not the place to expand on techniques or discuss philosophy, and the conclusions that it expresses have to be an accurate reflection on what was found. Abstracts should be not used to exaggerate the significance of the work and they should not contain subjective opinions on this importance or speculate how a material might be used. Very commonly submitted abstracts will include a phrase such as 'material X is very biocompatible and shows promise for use in orthopedic implants'. This is rarely a sensible approach to writing an abstract. The instructions specify a length of 100 to 200 words. Most good abstracts are around 150 words in length.

The Introduction

The Introduction, as the name implies, should introduce the background to the work that has been carried out, effectively providing the scientific rationale. It should contain sufficient citations to the key literature to support this rationale and should lead to a clearly stated hypothesis or set of objectives. Authors should assume that the readership is well-informed and there is no need for any generic educational background. For example, in a paper on wound healing it is not necessary to take the first page to explain the ideal characteristics of wound dressing materials, or in a paper on drug eluting stents it is not necessary to describe all of the competing technologies that address in-stent restenosis. The introduction should rarely be more than two manuscript pages long.

Units

The SI system should be used for all scientific and laboratory data; if, in certain instances, it is necessary to quote other units, these should be added in parentheses. Temperatures should be given in degrees Celsius. The unit 'billion' (10^9 in America, 10^{12} in Europe) is ambiguous and must not be used. If a large number of symbols are used it is helpful if authors submit a list of these symbols and their meanings.

The Materials and Methods

This section should specify exactly what was done experimentally, with sufficient detail for the reader to be able to repeat the experiments if he wishes. All of the experimental work discussed in the paper should be described in this section. Materials used in the work should be described in appropriate detail, including sources of commercial supply or synthetic routes, and all major equipment should be specified with the manufacturers name, reference number and location. Write in normal prose style; do not list instructions. You should describe what you did in past tense. Describe also measurements and calculations necessary to obtain final results.

The Results

Ideally the Results Section should be separate from the Discussion, but there is some flexibility here. The section should, obviously, be factual and it is best to avoid any philosophy or speculation. Authors should consider very carefully how to present their data. It should not be presented in multiple formats (i.e. the same data should not appear in figures and tables). If the data is displayed very effectively in either a table or figure, it should not be necessary to explain results in great detail in the text, but rather to use the text as a medium for emphasizing the most significant data.

The Discussion

This section should summarize the nature of the observations and attempt to place this data into the context of the existing body of literature and, where appropriate, to express opinions about the significance of the work as far as biomedical engineering is concerned. It should not be repetitive of the Introduction. It is entirely valid to suggest the potential implications of the work but without too much speculation. It is particularly important not to extend the discussion into areas that are not supported by the facts that are in evidence.

The Conclusions

Many authors end the Discussion section with a paragraph on the conclusions. This is not the best way to draw the manuscript to an end, and conclusions should be separated into a distinct section. This should not be too long, nor should it be repetitive of the discussion, and especially should not bring new ideas into the paper. The conclusions have to be based on the facts in evidence and should be limited to reasonable speculation about the significance of the work.

References

Instructions for the preparation of the list of references are given in the guidelines to authors. It is good to have a balance between the older seminal papers that lay the groundwork for that particular area and recent quality papers that have contributed serious input into the subject. Documents that have limited circulation, obscure journals or books, especially those out of date, and electronic sources (for example, web sites) should also be avoided.

All publications cited in the text should be presented in a list of references following the text of the manuscript. In the text refer to references by a number in square brackets on the line (for example, Since Peterson[1]), and the full reference should be given in a numerical list at the end of the paper. References should be given in the following form, which is designated Vancouver:

1. Driessens FCM, Boltong MG, Bermudez O, Planell JA. Formulation and setting times of some calcium orthophosphate cements: a pilot study. J Mater Sci: Mater Med 1993;4:503-508.

2. Nancollas H. In vitro studies of calcium phosphate crystallisation. In: Mann S, Webb J, Williams RJP, editors. Biomineralization. Chemical and biochemical perspectives. New York: VCH, 1989. p. 157-182.

3. Brown W, Chow LC. Combinations of sparingly soluble calcium phosphates in slurries and paste as mineralizers and cements. US Patent No. 4612053, 1986.

Figures and Tables

As noted earlier, experimental data should be represented in figures or tables wherever possible. Advice is not given here about the preparation of figures, detail being given in the guide to authors. Authors should note, however, that since figures and tables take up a considerable amount of space, they should be limited in number. Many authors used flow charts to represent experimental strategy or line drawings or photographs of equipment, most of which are unnecessary. Sometimes multiple figures are used with very little data on each, and which could be consolidated.

Figure and table captions should be constructed with care. There should be sufficient information for the reader to understand the subject matter, but it is not necessary to write an extensive text to explain all the detail.

You should consult the web site for more information. The journal itself is also accessible electronically, so feel free to peruse the articles for additional examples. You'll have to access the journal through the university library web site. The online journal web site is http://www.lib.utexas.edu/journals/. Search for "Biomaterials". This will automatically take you to the Biomaterials Journal web site. You can, however, only access the electronic journal from a campus computer. Hard copies are available for your reference in the lab.

Finally, keep in mind that this is a *group* assignment. That means all group members will receive the same grade. You should proof-read the entire report, even sections that were assigned to your group mates, before submitting it. Your name on the report implies that you will take full responsibility of its contents.

Below are some additional guidelines for writing the long report:

Abstract

This is the most important section of your long report. In fact, the reader's first impression of the overall report is frequently formed after reading the abstract. A well-prepared abstract therefore enables the reader to identify the basic content of the document quickly and accurately, to determine its relevance to his/her interest, and to decide whether or not he/she needs to read the document in its entirety.

A useful abstract is a complete, accurate, and concise summary of your long report. It is an actual condensation of the subject matter; the reader should therefore be able to grasp the major findings of the report and their relative importance and relationships from reading the abstract. The abstract should include a quantitative summary of what you did, the results you obtained, and the conclusions based on these results. The range of numerical values should be given for important parameters, variables, and results. The abstract, however, is not a textual table of contents.

Although the abstract is generally the first section that is read, it should be the last part of the report to be written. The construction of the abstract is the last step of an arduous job. Despite its importance, students are apt to throw the abstract together as fast as possible. For many students, it is a relief to finish the report; hence, they spend very little time on the abstract. The time spent in learning the "general rules" that govern the construction of a good abstract will pay high dividends in the end.

1. Write the abstract last, after you have written the entire report.
2. Make sure you cover these five main points in your abstract:
   a. the principal objectives and the scope of the experiment
   b. the methodology employed
   c. quantitative results
   d. conclusions
   e. recommendations
3. Do not cite references to the literature (this includes references to sections of the main body of the text, figures, tables and bibliographic information) in the abstract. Do not put figures or tables in the abstract. Equations should not be numbered.
4. The abstract should be self-contained. Most abstracts will, at some point, be separated from the parent report. It is therefore important that the significant results, conclusions, and recommendations must be included. The program committees of many engineering conferences will often use abstracts (and only abstracts) as the basis for accepting papers to be presented.
5. The abstract should never give any information or conclusion that is not stated in the main body of the report.

Technical Memos

Most of the reports written during the first ten years of an engineer's career are of the "technical memo" variety. They are intended for the first few levels of management above the writer. This simple vehicle may be the primary means by which your laboratory director or plant manager knows who you are and what you are doing. Bear in mind that this director is flooded with such reports every month. The director wishes to find out, with a minimum of wasted time, what is going on under his/her responsibility, why it is going on, and if it should continue to go on at the same, a higher, or a lower level of intensity. The only thing worse than submitting consistently lackluster or unreadable monthly reports is to submit one that catches everyone's attention when it doesn't deserve to. (An old IBM dictum: Be careful about what you call a good idea. Someone on top may believe it really is a good idea and put you in charge of delivering it.)

Alas, BME 221 technical memos are a paltry shadow of the real thing. Properly measuring the performance of glucose sensor will not bring that promotion that makes your mortgage affordable. Nevertheless, perhaps we can do something to get you started right. That is why we have decided to have you prepare reports in this brief format.

The objectives of a technical memo are different from those of a lengthy report (which you will also have an opportunity to write) and hence the style is different. A technical memo is written to an audience that knows in general terms what you are doing and why you are doing it. Hence your goal in a technical memo is to succinctly state the results from your studies and your conclusions.

Any discussion of the experiment should be limited to deviations from the expected. If you modify the experiment or obtain anomalous results you may choose to discuss those, but do not dwell on material provided in the handout. The technical memos should be short and to the point. Excesses in technical memos will be detrimental to your grade.

The format of the technical memo is less regimented than for a publication style paper. The guidelines below are a framework for you to work from:

1. The body of technical memos should not exceed 4 pages. The TAs are instructed to deduct points when the page limit is exceeded. This four-page limit includes figures and tables. The report should be stapled or bound and delivered with a letter of transmittal to the teaching assistants. The report may be single or double column format, with 1" margins top and bottom and 1" margins left and right. The submission should be single-spaced, with 12-point font.

   Figures and tables should be cut and pasted into the text, with captions and titles. Figures and tables should be legible, with no labels or entries reproduced having a size smaller than 10-point font.

   Note: Remember that the bulk of your technical memo should be in past tense because you are talking about an experiment you have completed. You should, however, use present tense when describing equipment. Technical memos should be written in 3rd person exclusively.

2. It is not necessary to divide a technical memo up into the same sections as used in a technical paper. It does aid the reader to provide some logical break points in your report.

   One possible division is:

   - Introduction
   - Experimental Methods and Analysis
   - Results and Discussion
   - Conclusions and Recommendations

   Note: Make a heading for each section of your report, left justify it and put it in bold font

3. Your technical memo should start off with a brief introduction that includes both the objectives of your experiment, and the basic procedures you employed. Even though you supervisor knows your general working assignment, supervisors generally read many of these reports and they need 1-2 short paragraphs to put the work in context. You do not need to provide general background (for example, why biomedical engineering is good for the world), but your introduction should focus on the specific objectives of your work.
4. The experimental methods do not need to be detailed, but a brief overview of what equipment was used and the quantities measured should be summarized in a few sentences. The experimental results should be succinctly summarized. Do not try to report all the raw data. Report a sample data set and summarize the methods of analysis, reporting only the key equations used for analysis (do not provide derivations unless you are reporting a novel method of analysis – and in that case the derivation may be provided in an appendix). In a technical memo, it is effective to discuss the implications of the results immediately after presenting them. Comparisons of the results to the literature or models may also be included here.
5. The technical memo should end with conclusions drawn from the experiments and recommendations for future work. You want to make sure your manager knows precisely what the implications of your work is, and you need to make it explicit if additional work is warranted, and what the scope of the proposed work is. In the case of the BME 221 technical memos, your recommendations should focus on potential improvements to the experimental measurements you made.

The general rule of thumb for technical memos: the introduction should tell the reader what to expect, the main body of text should report the results, and the conclusions should reiterate the key results you want the reader to remember!

Two copies of technical memos (one for the English TA and one for your technical TA) should be handed in at the beginning of the lab period on the due date. Late technical memos will not be accepted.

Writing Evaluation Rubrics

The instructor and TAs will evaluate your various writing assignments during the semester using the following rubrics.

Long Report Evaluation

BME UG Lab Long Report	**Students:** _____ **Project Title:**_____ Date:_____ Evaluated By:_____	**Score**
Technical Content	**Introduction/Background**: • Is the problem clearly defined, and placed into proper context within the existing knowledge base? • Has the group investigated the problem and state of current knowledge?	
	Quality and quantity of data: • Are the data what could be expected from a well-prepared group, and has the group exercised appropriate care in the collection of their data? • Is adequate detail given on the experimental design and data collection that someone at another institution could repeat the results?	
	Data analysis: • Have the data been analyzed in a sensible fashion? • Have major sources of error been identified and quantified to the extent possible?	
	• Is a technical understanding of the experiment reflected throughout?	
		___ of 10
Abstract	• Does the abstract communicate the purpose and principal findings? • Does it conform to the length restriction?	
		___ of 2
Style and Presentation	**Mechanics of organization:** • Does the document conform to the format of a manuscript to be submitted to *Biomaterials*, including length? • Does the report effectively convey the information? • Is there a logical sequence to the material presented? • Is information properly put in the main body, as its importance dictates? • Are statements appropriately referenced?	
	Writing style: • Does the document read smoothly and hold the reader's interest? • Any particular examples of poor phrasing, word choice, *etc*.	
	Clarity of tables and figures: • Are the tables and figures legible? • Is the choice of tables vs. figures to present data appropriate? • Are figures constructed so as to make their point at first glance?	
	Appearance: • Does the report look professional—at least prepared with care? • Are there significant typographical errors, misspellings, *etc*.?)	
		___ of 3
Score (0 to 15 possible)	**Total :**	
Comments		

Technical Memo Evaluation

Both technical content (50%) and style/presentation (50%) will be evaluated.

BME UG Lab Technical Memo	**Student:** _____ **Project Title:**_____ Date:_____ **Evaluated By:**_____	**Score**
Technical Content	**Quality and quantity of data:** • Are the data what could be expected from a well-prepared group, and has the group exercised appropriate care in the collection of their data? • Is adequate detail given on the experimental design and data collection that someone at another institution could repeat the results?	
	Data analysis: • Have the data been analyzed in a sensible fashion? • Have major sources of error been identified and quantified to the extent possible?	
	• Is a technical understanding of the experiment reflected throughout?	
		____ of 10
Style and Presentation	**Mechanics of organization:** • Does the report effectively convey the information? • Is there a proper introduction, and a logical sequence to the materials presented? • Does the report conform to the length limit?	
	Writing style: • Does the document read smoothly and hold the reader's interest? • Is the information communicated in an effective manner? • Any particular examples of poor phrasing, word choice, *etc.*	
	Clarity of tables and figures: • Are the tables and figures legible and properly labeled? • Is the choice of tables vs. figures appropriate? • Do figures make their point at first glance?	
	Appearance: • Does the report look professional—prepared with care? • Are there significant typographical errors, misspellings, *etc.*?)	
		____ of 10
Score (0 to 20 possible)	**Total :**	
Comments		

English Component Grading Scheme

The English component is worth 10% of the total grade for organization/style.

- Punctuation errors = -1/3 point
- All other errors = -3/4 point

BME UG Lab English Usage	**Students:** _____ **Project Title:**_____ Date:_____ Evaluated By:_____	**Possible**	**Score**
Sentence Construction: Does the paper demonstrated a variety of sentence forms, avoid awkward or run-on sentences, and generally make sense at the sentence level?		10	
Paragraph Organization: Do the paragraphs flow well? Are they logically organized, and is the paper concise and to the point?		10	
Point of View: • 10____Does the paper employ appropriate verb tense? • 10____Does the paper employ passive voice and 3rd person point of view throughout?		20	
Editing: Is the paper grammatically correct, spell-checked, and properly punctuated?		20	
Word Choice: • Does paper employ a variety of words, or are the same words used repetitively? • Are the words and terms chosen the most effective for the paper?		10	
Format: • 3_____Are all the required components placed in the appropriate order? • 3 ____ Length of Paper: Does it fit within the assignment guidelines? • 2 ____ Margins and Paragraphs? • 2 ____ Numbering of Pages? • 2 ____ Sentence Spacing? • 2 ____ Headings and Subheadings: Are headings and subheadings placed appropriately? Are they effective for organizing the paper? • 3 ____ Does the student use correct labels for Equations, Figures, and Tables? • 1 ____ Signatures? • 2 ____ Neatness?		20	
Components of Paper: • 10 ____References: Does the student place references where needed? Is the correct citation form used?		10	
Score (0 to 100 possible)		**Total :**	
Com-ments			

Index