Name(s):	Period:	Date:

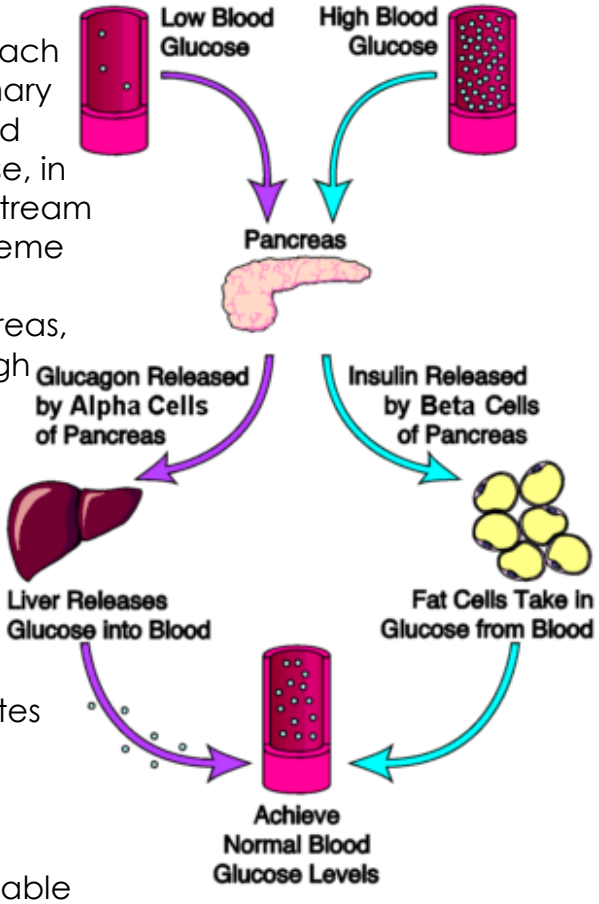
Homeostasis FAIL: A System Out of Balance

HASPI Medical Biology Lab 04b

Background/Introduction

Regulating Sugar in The Blood

The **pancreas** is a small organ that sits behind the stomach and produces hormones and enzymes. One of its primary functions is to produce two hormones called **insulin** and **glucagon** that regulate the amount of sugar, or glucose, in the blood. Too much or too little glucose in the bloodstream can have an adverse impact on the body, and in extreme cases can even lead to death. The body controls the amount of insulin and glucagon released by the pancreas, and therefore the amount of sugar in the blood, through negative feedback mechanisms.

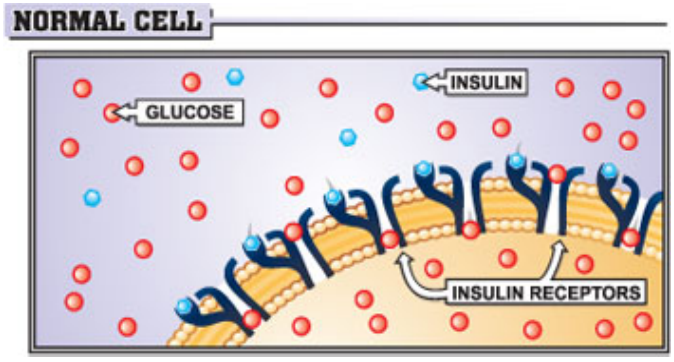


http://bio1152.nicerweb.com/Locked/media/ch45/45_12GlucoseHomeostasis.jpg

Negative Feedback: Insulin, Glucagon, and Glucose

After you eat a meal, the large molecules of proteins, fats, and carbohydrates are broken down into smaller molecules that can absorb into the bloodstream through the process of digestion. **Glucose** is a small molecule that results from the digestion of carbohydrates and is required for cellular respiration within cells.

As glucose is absorbed into the bloodstream following digestion, the blood sugar level rises above normal, signaling the pancreas to release insulin. Glucose is unable to pass into the cells of the body on its own and needs insulin to assist. Insulin essentially "opens the door" to allow glucose to move into cells, which need the glucose to perform cellular respiration and create energy in order to function.



http://pre-diabetes.insulitelabs.com/

As glucose leaves the bloodstream into cells, the blood sugar level drops. The body must compensate to return the blood sugar level to normal. When blood sugar levels are lower than normal, the pancreas is signaled to stop releasing insulin and release glucagon. Excess glucose can be stored in liver and muscle cells. Glucagon causes excess glucose stored in liver and muscle cells to be released.

The back and forth between insulin and glucagon to maintain a normal amount of glucose in the blood is a great example of how the body uses negative feedback to maintain homeostasis within the body. Remember that negative feedback is when the body corrects imbalances back to normal values. So, what happens if this negative feedback becomes imbalanced?

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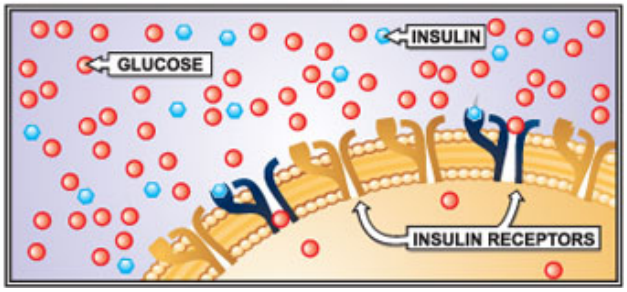
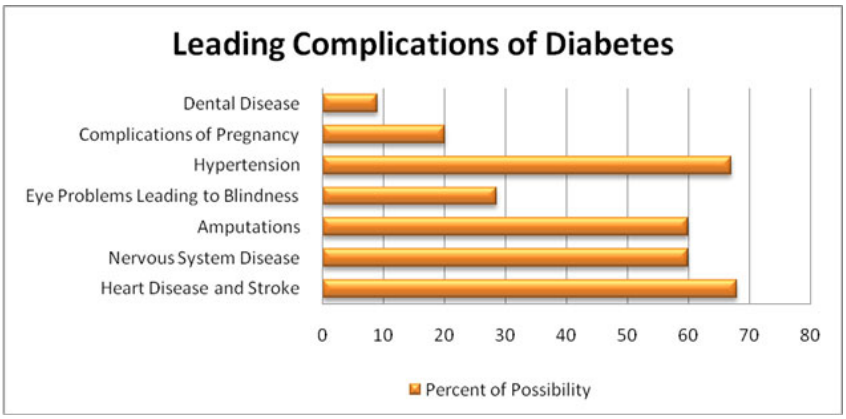
Diabetes: Homeostasis FAIL



http://pre-diabetes.insulitelabs.com/images/cell_ir_01.jpg

Diabetes is a group of diseases, all of which are characterized by abnormal blood glucose levels that result from the inability of the body to produce and/or use the hormone insulin. Insulin is produced by the pancreas and is needed to maintain normal glucose levels in the blood. If insulin is either not produced or cells become resistant to insulin, the level of sugar in the blood continues to rise. The negative feedback controls that should maintain the normal blood sugar level are thrown off and the homeostatic imbalance, known as diabetes, occurs.

Generally, diabetes is separated into Type 1 and Type 2. **Type 1 diabetes** is a genetic disease that is normally diagnosed very early on in life, and results in the body not producing insulin. **Type 2 diabetes** is the most common form and results when the body does not produce sufficient amounts of insulin OR when cells become insulin resistant. Type 2 diabetes can be hereditary, but is strongly impacted by diet and exercise. A condition known as **pre-diabetes** is present before the onset of Type 2 diabetes, and more than 79 million people in the U.S. have pre-diabetes.



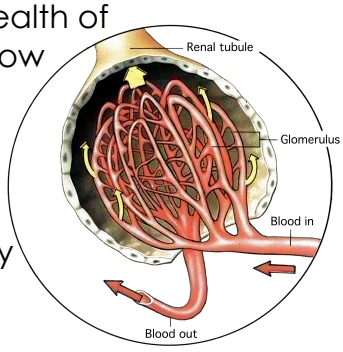
http://media.mercola.com/Assets/images/infosite/diabetes/leading-complications-diabetes.jpg

Diabetes can cause a wide variety of symptoms including frequent urination, frequent thirst, extreme hunger, recurring infections, fatigue, vision loss, reduced healing, limb numbness, increased cancer occurrence, and high blood pressure just to name a few. More importantly, these symptoms can lead to further complications if diabetes is left uncontrolled.

The American Diabetes Association estimates that more than 11% of the U.S. population has diabetes, and approximately 54% of long-term hospital patients that are hospitalized have conditions resulting from complications with diabetes.

Diabetes and High Blood Pressure: An Example of Positive Feedback

Diabetes has a large array of symptoms that can adversely impact the health of an individual. One of the symptoms of diabetes is high blood pressure. How diabetes causes higher blood pressure provides an example of a positive feedback loop. The kidneys are the most important regulator of blood pressure through balancing the amount of fluids and substances in the blood. The filtering units of the kidneys are called **glomerulus,** and are surrounded by dense networks of capillaries. These capillaries have a very thin surface, allowing substances and fluids to diffuse in/out of the blood and in/out of the glomerulus. Any excess fluids or substances are passed on to the bladder and secreted as urine.



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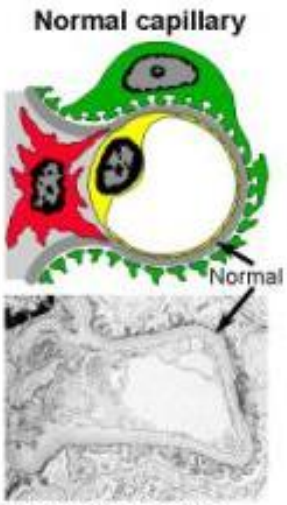
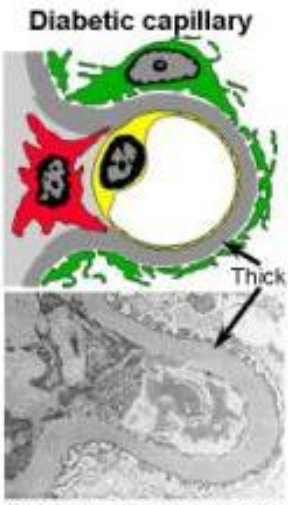


Diagram and electron microscopic photograph of a cross section of a normal glomerular capillary. The basement membrane is normal.



Cross section of a glomerular capillary injured by diabetes in a kidney biopsy specimen. The basement membrane is abnormally thick compared to normal.

http://www.unckidneycenter.org/images/diabetesgraphic.jpg

High amounts of sugar in the blood damages capillaries by causing them to thicken and degrade. When this happens, less fluids and substances are able to diffuse through the glomerulus into the kidneys. When this happens, the kidneys sense that less blood is passing through the capillaries and sends hormones that increase blood pressure so more blood is passing through the capillaries. Essentially, the kidneys are trying to return the body to "normal" blood pressure, not realizing the problem is that less blood is able to pass through the damaged capillaries.

The more damage to the capillaries caused by high blood sugar, the higher the kidneys raise the blood pressure as they try to correct the imbalance. It becomes a vicious cycle causing extensive damage that will eventually lead to death without regulation of blood sugar levels.

Blood Glucose Level Testing

Since an individual with diabetes has abnormal amounts of glucose in the blood, and his or her body is unable to control these amounts, it is important for diabetics to perform tests to check their blood glucose levels. If these levels are drastically high or low it can result in coma and eventually death; hence the importance of knowing the levels! Diabetes medications and insulin can assist a diabetic in balancing his or her glucose levels if an imbalance is detected.

Review Questions – *answer questions on a separate sheet of paper*

1. What is the pancreas and how does it assist the body in maintaining the amount of glucose in the blood?
2. What is the purpose of glucose in the body? Hypothesize why it is so important for your body to have a constant supply of glucose.
3. Explain how insulin and glucagon help the body maintain normal blood glucose levels.
4. Hypothesize why glucose needs insulin to enter cells.
5. Give and explain an example (other than temperature or blood sugar levels) of how the body uses negative feedback to maintain homeostasis.
6. What causes diabetes?
7. What is the difference between Type 1 and Type 2 diabetes?
8. What are the 4 most common leading complications of diabetes?
9. Explain in detail how high blood sugar and high blood pressure demonstrate a positive feedback loop.
10. Why is it important for a diabetic to perform regular blood glucose level tests?

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HASPI Medical Biology Lab 04b

Scenario

You work in the laboratory at HASPI Hospital, and have been tasked with performing a blood glucose test on three patients displaying symptoms that may indicate diabetes. Background information for each of your patients has been included below.

Patient A

Mr. Gomez is a 31-year-old Hispanic male. He is 5'5" tall and weighs 315 lbs., which puts him in the category of morbidly obese according to the Body Mass Index (BMI). Within the past week, he has been quick to anger and thirsty all the time. He often feels like he needs to get up in the middle of the night to get a glass of water. There is no history of diabetes in his family. Mr. Gomez does not exercise, and his diet consists of foods high in sodium.

Patient B

Mr. Davis is a 49-year-old African-American male. He is 6'0" tall and weighs 215 lbs., which puts him in the category of overweight according to the BMI. He has noticed an increase in his thirst, urination, and hunger in the past few weeks. In addition, he has felt some tingling in his feet and toes, which is the main reason he has visited his doctor. His grandfather had Type 2 diabetes, but he was not diagnosed until he was 69 years old. Mr. Davis exercises 1-2 days a week, and his diet consists of mostly carbohydrates and lots of sugar.

Patient C

Ms. Baloc is a 21-year-old Caucasian female. She is 5'2" tall and weighs 115 lbs., which puts her at a normal weight according to the BMI. In the past month, she has noticed a large increase in the amount of times she needs to urinate. She finds herself even needing to get up several times in the middle of the night, which she never had to do before. She came to her doctor for testing as a result of nausea and vomiting over the past week. Ms. Baloc has two aunts who have diabetes, exercises inconsistently, and her diet consists primarily of proteins and starch.

Materials

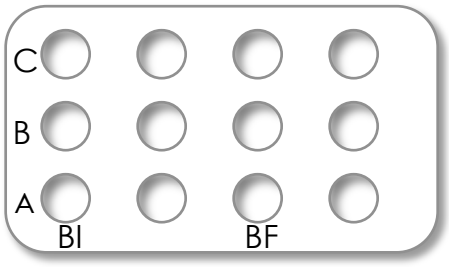
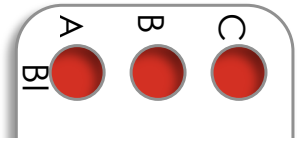
Initial Blood A
Final Blood A
Initial Blood B
Final Blood B
Initial Blood C
Final Blood C
6 Glucose Test Strips
Glucose Test Chart
Spot Plate
Wax Pencil
Paper Towels

Procedure/Directions

Your lab team will be given tasks, or directions, to perform on the left. Record your questions, observations, or required response to each task on the right.

PART A: Initial Blood Glucose Test		
	Task	**Response**
1	Based on the patient backgrounds, predict which patients have diabetes, as well as what type (pre-diabetes, Type 1, or Type 2).	Patient A: Patient B: Patient C:

Name(s):	Period:	Date:

	Task	Response
2	Obtain a spot plate. Using a wax pencil or other writing device, label the wells of the spot plate as seen in ***Figure A***. A, B, and C are for each patient, while BI is "Blood Initial" and BF is "Blood Final."	**Figure A** 
3	Add 3-5 drops of Initial Blood for Patients A, B, and C to the appropriate wells on your spot plate. Make sure to keep the samples separate on your spot plate.	
4	Using a glucose test strip, dip the strip into the Initial Blood sample or Patient A for 1-2 seconds and remove. Place the glucose test strip on a paper towel.	
5	Wait 2 minutes, and then compare the color of the test strip with the glucose test chart.	*a. Why do you think it is important to wait the full 2 minutes before looking for results?*
6	Record the results in Data Table 2 below.	
7	Repeat steps 4-7 for the remaining Initial Blood samples for Patients B and C.	
8	Complete Data Table 2 by comparing your patients' results with the normal blood glucose levels provided in Data Table 1.	
9	Based on the results, complete the ***Patient Initial Diagnosis and Treatment*** forms for your patients. You may need to research the best treatment course for each patient based on the diagnosis.	

Data Table 1. Normal vs. Abnormal Glucose Levels *(milligrams/deciliter)*

Blood Glucose Test	Hypoglycemia	Normal	Pre-diabetes	Hyperglycemia
	> 40 mg/dL	40 – 99 mg/dL	100 – 125 mg/dL	< 126 mg/dL

Data Table 2. Initial Glucose Test Results

	Initial Glucose Level (mg/dL)	Comparison to Normal Values (amount + or – normal)	Indications (hypoglycemic, normal, pre-diabetic, or diabetic)
Patient A			
Patient B			
Patient C			

Name(s): **Period:** **Date:**

Patient A. Initial Diagnosis and Treatment

Blood Glucose: _____ Diabetes Status/Type: _____

Background Indications of Diabetes: _____

_____

Treatment Plan: _____

_____

_____

_____

Patient B. Initial Diagnosis and Treatment

Blood Glucose: _____ Diabetes Status/Type: _____

Background Indications of Diabetes: _____

_____

Treatment Plan: _____

_____

_____

_____

Patient C. Initial Diagnosis and Treatment

Blood Glucose: _____ Diabetes Status/Type: _____

Background Indications of Diabetes: _____

_____

Treatment Plan: _____

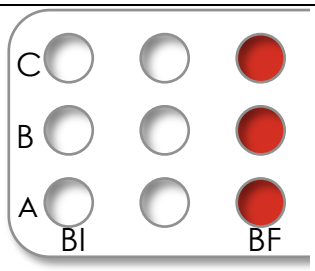
_____

_____

_____

Name(s):	Period:	Date:

PART B: Final Blood Glucose Test

	Task	Response
1	Fast forward to 4 weeks later. Your patients have returned for a check-up and retesting to determine if their diabetes status has changed. ***Patient A**: Mr. Gomez did not follow your advised treatment plan.* ***Patient B**: Mr. Davis sporadically followed your advised treatment plan.* ***Patient C**: Ms. Baloc followed your treatment plan as advised.*	
2	Add 3-5 drops of Final Blood for Patients A, B, and C to the appropriate wells on your spot plate. Make sure to keep the samples separate on your spot plate.	
3	Using a glucose test strip, dip the strip into the Final Blood sample for Patient A for 1-2 seconds and remove. Place the glucose test strip on a paper towel.	*a. Hypothesize why it is important to test blood glucose levels regularly if an individual has been diagnosed as diabetic.*
4	Wait 2 minutes, and then compare the color of the test strip with the glucose test chart.	
5	Record the results in ***Data Table 3*** below.	
6	Repeat steps 4-7 for the remaining Final Blood samples for Patients B and C.	
7	Complete ***Data Table 3*** by comparing your patients' results with the normal blood glucose levels in ***Data Table 1*** and the initial results from ***Data Table 2***.	

DATA TABLE 3: Final Blood Glucose Results

	Glucose Level *(mg/dL)*	Comparison to Normal Values	Change from Initial Glucose Level	Has this patient improved, worsened, or stayed the same?
Patient A				
Patient B				
Patient C				

Name(s): **Period:** **Date:**

Analysis & Interpretation

Answer the following questions using data from your lab AND internet research if needed.

Analysis Questions – *answer questions on a separate sheet of paper*

Part A

1. Why is it important to use separate test strips for each glucose test?
2. Explain how glucose levels become elevated in the blood of a person with diabetes.
3. What occurs in the body of a diabetic patient that allows for large amounts of glucose to be found in the urine?
4. How closely did your predictions compare to the actual results?
5. Hypothesize why it is important that a patient fasts before a urine or blood glucose test.

Part B

1. Why do you think it is difficult for some individuals to follow an advised treatment plan, such as Patients A and B?
2. With the treatment plans in place, did any of the patients' final tests improve from their initial tests? Hypothesize why or why not?
3. How does a homeostatic imbalance, such as diabetes, provide evidence for feedback mechanisms that maintain homeostasis?
4. List at least 5 body systems or organs that are affected by diabetes.
5. What are the acute, or short-term, consequences of diabetes if left untreated?
6. What are the major, or long-term, consequences of diabetes if left untreated?
7. What type of lifestyle changes do people with diabetes have to make?
8. How can diabetes be prevented?
9. Why is diet and exercise important to helping to maintain the balance between insulin and glucagon?

Connections & Applications

Your instructor may assign or allow you to choose any of the following activities. As per NGSS/CCSS, these extensions allow students to explore outside activities recommended by the standards.

1. **RESEARCH ALCOHOL POISONING:** Excessive alcohol use is attributed to more than 80,000 deaths yearly in the U.S. Research alcohol poisoning to answer the following:
   a. What are symptoms of alcohol poisoning?
   b. How does alcohol impact homeostasis?
   c. Specifically, how does excessive alcohol inhibit feedback mechanisms?
   d. What are treatment options for someone suffering from alcohol poisoning? How do these treatment options impact homeostasis?
   e. Correctly cite at least 3 resources.

Name(s):	Period:	Date:

2. **CALCULATING KIDNEY DAMAGE:** The speed at which kidneys filter is called the **glomerular filtration rate**, or **GFR**. GFR is the best test to measure a person's level of kidney function. The normal GFR rate is **125 ml per minute (ml/min)**, which is about 180 liters per day. In an individual with diabetes, the kidneys become damaged over time and the filtration rate is reduced. A simple sugar called **inulin**, not to be confused with insulin, is injected into the body. The urine produced from the test is monitored to determine how long it took the kidneys to rid inulin from the body. The following equation then allows a physician to determine the GFR:

$$GFR = \frac{V \times U}{P}$$

What do these mean?
GFR = Glomerular Filtration Rate
V = volume of urine (ml/min)
U = concentration of inulin in the urine (mg/ml)
P = concentration of inulin in the blood (mg/ml)

Calculate and graph data collected from GFR tests over a 20-year period for your three patients (A, B, and C). The following table summarizes the test results from GFR tests performed every 4 years. Calculate each of the patient's GFR from the test results provided. When complete, graph each patient's GFR over time and determine what each patient's results conclude in terms of kidney damage.

PATIENT GFR RESULTS		Initial Test: 0 years	4 years	8 years	12 years	16 years	20 years
Patient A	Urine Volume (ml/min)	0.99	1	0.99	1	0.98	0.95
	Urine Inulin Concentration (mg/ml)	124	123	122	120	120	119
	Blood Inulin Concentration (mg/ml)	0.98	0.99	1	1.03	1.08	1.1
	Glomerular Filtration Rate (GFR) ml/min						
Patient B	Urine Volume (ml/min)	0.98	1	0.98	0.94	0.89	0.81
	Urine Inulin Concentration (mg/ml)	126	123	120	119	115	106
	Blood Inulin Concentration (mg/ml)	1.1	1.12	1.11	1.12	1.11	1.13
	Glomerular Filtration Rate (GFR) ml/min						
Patient C	Urine Volume (ml/min)	1	1	0.99	0.99	1	0.99
	Urine Inulin Concentration (mg/ml)	125	123	124	124	124	123
	Blood Inulin Concentration (mg/ml)	1.01	1.01	1.02	1.03	1.05	1.04
	Glomerular Filtration Rate (GFR) ml/min						

Name(s):	Period:	Date:

3. **DIABETES RISK ASSESSMENT:** The following survey is a diabetes risk test. If an individual answers yes to any of the questions, he or she may be at risk for developing diabetes. Survey at least one person in each of the following age groups:

Age Group
5 – 19 yrs. old
20 – 29 yrs. old
30 – 39 yrs. old
40 – 49 yrs. old
50 + yrs. old

For each individual you survey, create a table to determine:

a. How many "YES" answers the person gave from the survey.
b. Whether the person is at risk for developing diabetes OR already has been diagnosed with diabetes.
c. What measures he or she might take to reduce the risk.

Diabetes Risk Test - Are you at risk for diabetes?

Answer Yes or No to the following questions:

1. Are you between the ages of 40-64?
2. Do you have a blood relative with diabetes?
3. Have you had a baby weighing over 9 pounds?
4. Do you rarely exercise (once a week or less)?
5. Are you overweight according to the BMI scale?
6. Do you urinate excessively?
7. Are you always thirsty?
8. Have you lost weight for no reason?
9. Do you often have numbness or tingling in your legs or feet?
10. Do you have blurred vision?
11. Are you always tired?
12. Are you African-American, Hispanic, Native-American, Asian-American, or a Pacific Islander?

A "yes" answer to 2 or more of the above questions puts you at high risk for developing diabetes. The more "yes" answers, the higher the risk.

Resources & References

- Cohen, R.M. and Sadler, L. 2006. Diabetes and the Body: Pancreatic Function. NetWellness. http://www.netwellness.org/healthtopics/diabetes/pancreasdiabetes.cfm.
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- Stalheim-Smith, A., Gaines, R., and Robinson, S. 1993. Laboratory Manual for Understanding Human Anatomy and Physiology, West Publishing.
- Weber, C. 2008. High Blood Pressure & Diabetes – A Positive Feedback Loop. http://highbloodpressure.about.com/od/highbloodpressure101/a/feedbackloop.htm.