Lesson Five

Anatomy and physiology of type 2 diabetes

Overview
Students develop a detailed human body poster that shows the many organs and body systems impacted by type 2 diabetes and learn about the damage done to each of those organs. They also learn about treatments for type 2 diabetes and their physiological targets.

Enduring understanding: If left untreated, type 2 diabetes (chronic elevated blood glucose) has devastating effects on many organs of the body and can lead to death. In the face of the growing epidemic, it is critical that we address ways to treat and prevent type 2 diabetes.

Essential question: What are the effects of type 2 diabetes on the body, and how can we treat these effects?

Learning objectives
Students will be able to:

- Create a human body poster that shows organs affected and damaged by type 2 diabetes.
- Explain treatment/prevention options for type 2 diabetes
- Evaluate the relative costs of diabetes prevention and diabetes treatment

Prerequisite Knowledge
Students should be familiar with the human body systems (circulatory, digestive, nervous) and body organs (heart, eye, kidney, stomach, intestines, pancreas, liver)

Time: Two 50 minute periods

This lesson connects to the Next Generation Science Standards in the following ways:

Performance Expectation
HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

Disciplinary Core Idea LS1.A: Structure and Function
Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.

This lesson uses the Scientific Practices of **Developing and Using Models** and **Obtaining, Evaluating and Communicating Information**. It also highlights the Crosscutting Concept of **Cause and Effect**, and **Structure and Function**.

Materials

Materials	Quantity
Computer and projector	1 per class
Lesson 5 PowerPoint presentation, found at: https://gsoutreach.gs.washington.edu/	1 per class
Computer and internet access	Per group
Large piece of butcher block paper, big enough to make a life-sized body outline of a student	1 per class
5 colors of construction paper, one for each body group (heart, brain, eyes, kidneys, and limbs)	1 color per group
Student Sheet 5: *Organs affected by type 2 diabetes* (two-sided)	1 per student
Student Resource: *On-line Reference Guide* (this could be cut into strips)	1 per group

Lesson Preparation

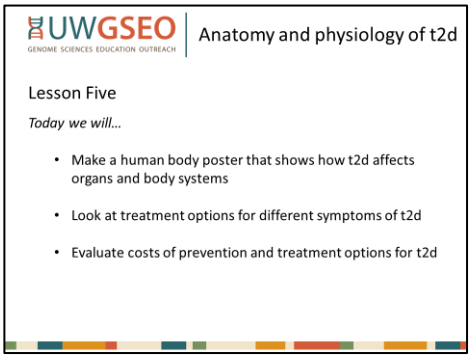
- Prepare a life-sized body outline before class, or have butcher paper available to do so at the beginning of class by tracing a student.
- Make sure that students have access to computers and the internet.
- Have Lesson 5 PowerPoint presentation ready to be projected.

Presenting the Lesson

Part 1 (Engage): Type 2 diabetes: a growing epidemic (*10 minutes*)

1. Show students PowerPoint Slide 1 to introduce the lesson to students.

Slide 1



2. Read the statement below to your class, or project slide 2 of the PowerPoint.

If current trends continue, 1 in 3 U.S. adults will have diabetes by 2050.

Source: Center for Disease Control and Prevention, http://www.cdc.gov/chronicdisease/resources/publications/aag/ddt.htm

Slide 2

3. Ask students to work in pairs to briefly discuss:
    - What do you know about the effects of type 2 diabetes on the body?
    - How are these symptoms treated?
    - What would happen if 1 in 3 adults in the U.S. had type 2 diabetes?

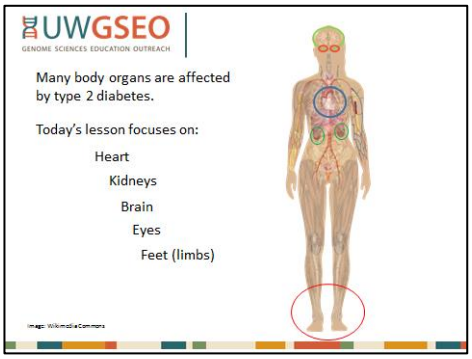
4. As a class, discuss and record student responses to the three prompts. Ask students what aspects of the symptoms/effects of t2d they would like to learn more about, and record these questions.

Part 2 (Explore): Organs affected by type 2 diabetes (*30 minutes*)

5. Make (or show) one full-sized body poster made of butcher paper for the class to use. Hang the poster in a place that is accessible to students. Ideally, the poster could be left up for the duration of the unit, so that the class could continue to add information to the poster.

6. Use Slide 3 to give a body overview and discuss the body organs and systems affected by type 2 diabetes. Refer back to the symptoms/effects students mentioned earlier, when possible.

Slide 3



Note: Teachers may wish to have class teams research and report back on more than five organs affected by type 2 diabetes. The Teacher Resource at the end of this lesson suggests additional organs or organ systems that are affected, such as the pancreas, skin, lungs, stomach, intestines, and others.

7. Hand out Student Sheet 5: *Organs affected by type 2 diabetes*. Tell student that they will be working in teams to learn more about each organ listed on Table 1 and on the slide.

8. Split the class into 5 groups and assign each group an organ to research in more detail. Alternately, the class could be split into 10 or more groups, with two groups finding information about the same organ.

9. Hand out the Student Resource: *On-line Reference Guide* to each group (or hand out the strip of paper pertaining to their organ). This will be used to further research the effects of type 2 diabetes on that organ. Ideally, the links could also be provided in electronic form.

10. Hand out a piece of colored paper to each group. This will be used to draw and cut out a life-sized organ to be attached to the life-sized poster.

11. Have students begin researching in groups and record their findings for their organ on the front side of Student Sheet 5: *Organs affected by type 2 diabetes*.

12. When students have had enough time, students can report back to their classmates on what they have learned. Presenting students should come to the human body poster, attach their organ, and report back on their findings. The rest of the class can take notes on the organs other students have researched as they listen to their presentations.

> ***Note:*** This portion of the lesson can also be run as a jigsaw activity, in which students who have chosen the same organ first meet together to fully fill out the information for that organ on their tables on Student Resource 5. Students then regroup into mixed organ groups in order to teach each other about the other organs. Organs can be attached to the human body poster after the jigsaw is complete.

Part 3 (Explore/Explain): **How high blood glucose causes damage** *(20 minutes)*

13. After student groups have presented to each other, ask if there are any common themes about treatment and prevention (last column) across the different organs.

    Students may notice that damage to many of the organs can be prevented by lowering chronic high blood glucose level (controlling blood sugar) through lifestyle interventions like diet and exercise. Careful screening and medication may also play a part after diabetes has developed.

14. Point out for students the first column of their data table. Why does it say *Chronic High Blood Glucose*?

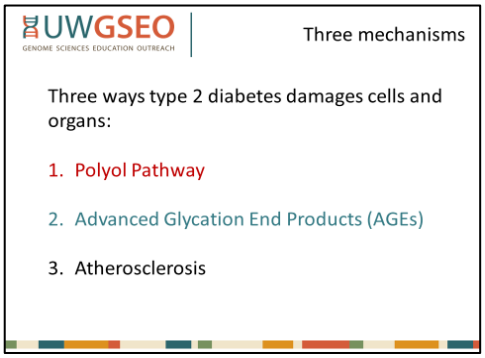
    Although different organs may sustain different types of damage, the root cause of type 2 diabetes is chronic high blood glucose levels. By controlling that, each organ can be affected.

15. Ask students to look at the column that asks *What causes the symptom*? Do they see any common pathway to damage among the organs they have studied? What damaged body systems contribute to the damage in the organ they studied?

    Student may notice that damage to blood vessels is a common theme. They may also notice that damage to nerves (neuropathy) contributes to damage in other organs.

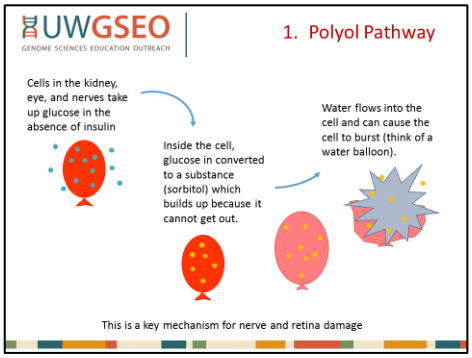
16. Use Slides 4 through 7 to discuss three major ways that high blood glucose and other changes in type 2 diabetes cause damage to cells, organs, and body systems. Slide 4 shows three types of primary damage that have a cascade effect on many organs.

Slide 4

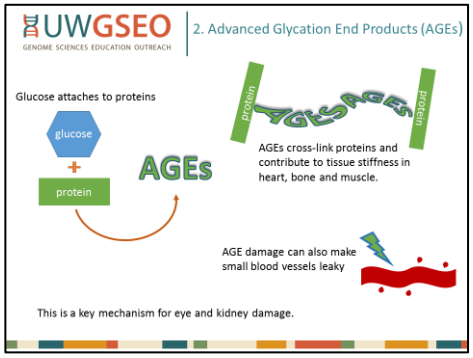


17. Slides 5 – 7 describe each of the mechanisms in more detail.

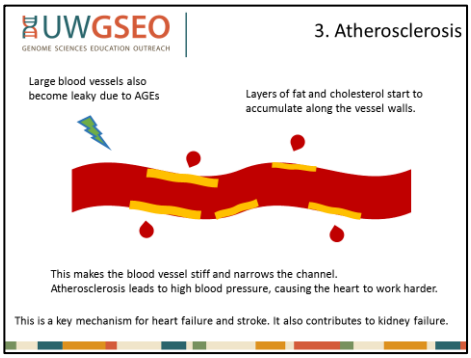
Slide 5



Slide 6



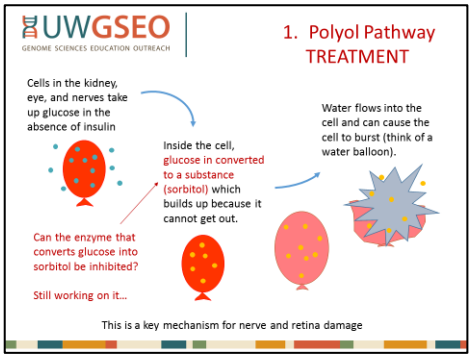
Slide 7



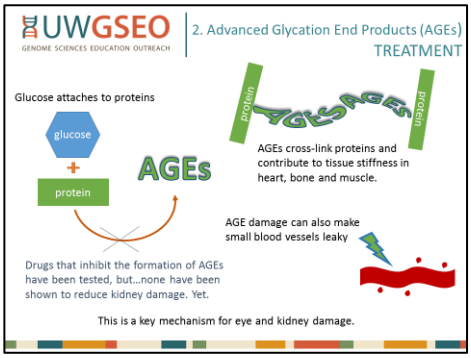
18. Ask students to work with their groups to relate these mechanisms to the organ they studied. If time allows, students could add this to the human body poster.

19. Show students slides 8 through 10. While treatments of all three of these mechanisms are being studied, none provides a perfect, or even good, solution.

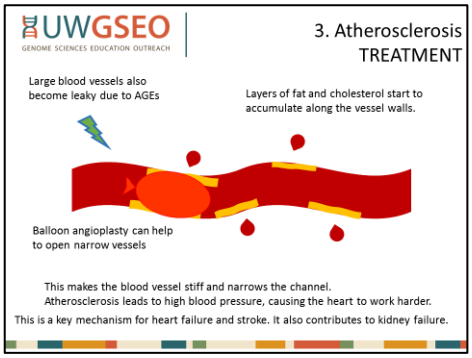
Slide 8



Slide 9



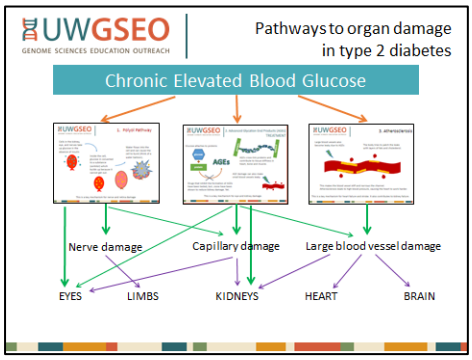
Slide 10



Part 4 (Elaborate): Treatment and cost (*20 minutes*)

20. Show students Slide 11. Underscore for students that the physiological mechanisms they have seen in this lesson are complex and interrelated, which makes treatment difficult and expensive. The green arrows show primary damage caused by the three mechanisms, and the purple arrows show the effects of damage to nerves, capillaries, and large blood vessels to other organs.

Slide 11

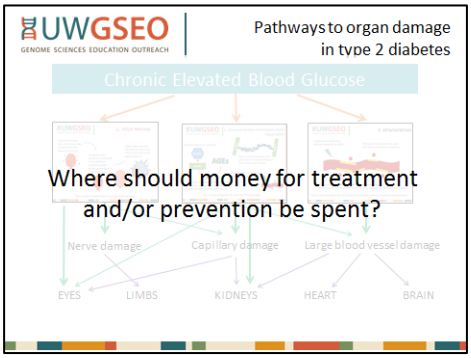


21. Share with students some of the financial costs of type 2 diabetes, per year. These statistics are from the year 2007, which was the latest year this information was available:
    - Direct medical costs for t2d: $116 billion
    - Indirect costs (related to disability, work loss, premature death): $58 billion
    - Total costs (direct and indirect): $174 billion
    - On average, medical expenses for a person with diagnosed diabetes are more than twice as much as the expenses of a person without diabetes.

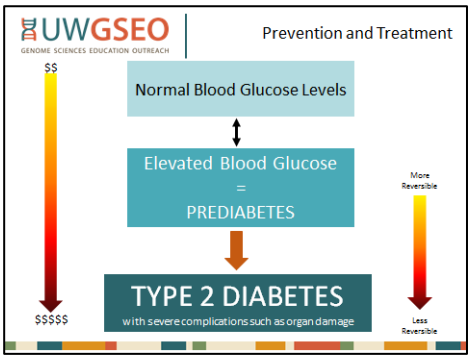
    Source: CDC, http://www.cdc.gov/chronicdisease/resources/publications/aag/ddt.htm

22. Show students Slides 12 and 13. Discuss the question, and point out that both prevention and treatment can start with the control of chronic elevated levels of blood glucose, through diet, exercise, and medication to help reduce insulin resistance.

Slide 13



Slide 12



23. Type 2 diabetes puts a financial burden on individuals, families, communities, and health care systems. Money needs to be invested in treatment options for people living with type 2 diabetes and, at the same time, money needs to be invested in prevention so that people do not become diabetic. ***Prevention, in the long run, is more cost effective than treating the effects of type 2 diabetes.***

Closure (Evaluate) *(10 minutes)*

24. Revisit the statement made at the beginning of the class:

    If current trends continue, 1 in 3 U.S. adults will have diabetes by 2050.

25. Ask students how old they will be in 2050. If prevention is more desirable than treatment, and they will be about 50 years old in 2050, at what point in time should their 50 year-old self take steps to prevent diabetes?

26. Ask students how this lesson contributes to their understanding of the Driving Question: ***How can the growth of type 2 diabetes in the Yakima Valley be slowed?*** and revisit the Question Wall to see if questions have been answered or more questions need to be added.

Please allow students time to work in groups on their Call to Action products. It will take a class period or two for groups to assimilate and integrate new information into their product, as well as refine their Call to Action plan. A *Group Planning Worksheet* and other resources can be found in the *Assessment* section at the end of this unit.

Heart

National Heart, Lung, and Blood Institute: http://www.nhlbi.nih.gov/health/health-topics/topics/dhd/

National Diabetes Information Clearinghouse (NDIC): http://diabetes.niddk.nih.gov/dm/pubs/stroke/#occur

American Diabetes Association: http://www.diabetes.org/living-with-diabetes/complications/heart-disease/

WebMD: Risks and complications in heart and blood vessels: http://www.webmd.com/diabetes/risks-complications-uncontrolled-diabetes

Genetic Health http://www.geneticheath.com/DBTS_Diabetes_Controlling_Type_2_Diabetes.shtml#Anchor2

Brain

National Diabetes Information Clearinghouse (NDIC): http://diabetes.niddk.nih.gov/dm/pubs/stroke/#occur

American Diabetes Association: http://www.diabetes.org/living-with-diabetes/complications/stroke.html

http://www.diabetes.org/research-and-practice/we-are-research-leaders/recent-advances/type-2-diabetes-deteriorates-brain-function.html

The Final Frontier: How Does Diabetes Affect the Brain? (advanced content): http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2797942/

Eyes

American Diabetes Association http://www.diabetes.org/living-with-diabetes/complications/eye-complications/

WebMD: Risks and complications in heart and blood vessels, eyes: http://www.webmd.com/diabetes/risks-complications-uncontrolled-diabetes

Genetic Health: http://www.geneticheath.com/DBTS_Diabetes_Controlling_Type_2_Diabetes.shtml#Anchor2

Kidneys

American Diabetes Association: http://www.diabetes.org/living-with-diabetes/complications/kidney-disease-nephropathy.html

Diabetic kidney disease: http://www.patient.co.uk/health/diabetic-kidney-disease-leaflet

Diabetes and kidney disease: http://www.kidney.org/atoz/content/diabetes.cfm

Diabetes and kidney failure:
http://www.betterhealth.vic.gov.au/bhcv2/bhcarticles.nsf/pages/Diabetes_and_kidney_failure

Genetic Health: http://www.geneticheath.com/DBTS_Diabetes_Controlling_Type_2_Diabetes.shtml#Anchor2

Feet (e.g. limbs)

American Diabetes Association http://www.diabetes.org/living-with-diabetes/complications/foot-complications/

Group Health Cooperative:
http://www.ghc.org/healthAndWellness/?item=/common/healthAndWellness/conditions/diabetes/nerveDamage.html&print=true

Pictures of organs and organ systems can be found at: **www.diabetes.co.uk/body/** and **http://commons.wikimedia.org/wiki/Human_body_diagrams**

Instructions: Make a life-sized organ using the colored paper. Reseach the organ using the sources on the other side of this handout, and fill in the correct columns.

Chronic High Blood Glucose	**Organ**	**Function** *(what does it do?)*	**What are some symptoms of type 2 diabetes in this organ?** *(stroke, ulcers, blindness…)*	**What causes the symptom?** *(leaky blood vessels, decreased circulation…)*	**How can the organ damage be treated or prevented?** *(screening, lifestyle changes, surgery, medicine…)*
	Heart				
	Brain				
	Eyes				
	Kidneys				
	Limbs (e.g. feet)				

Use the back of the sheet for additional space if needed.

Question:

Given a hypothetical 1 million dollars that you must spend to benefit the community in regards to type 2 diabetes, how would you spend the money? Why? Make sure to mention both prevention and treatment in your answer.

(Since it is difficult to know exactly how much things cost, you may use percentages, such as: *I would spend 50% of the money on prevention by building play grounds in elementary school so that school kids can get exercise, and 50% of the money on treatment by making sure that people without health insurance have the medication they need.)*

Additional notes:

Teacher Resource: Effect of Diabetes on Human Body Systems and Organs

Organ / Structure	Body System	Function	Effect of diabetes
Heart	Cardiovascular	The function of the heart, a grapefruit-sized organ, is to pump oxygen-rich blood throughout your body and oxygen-poor blood to your lungs.	**High Blood Pressure (Hypertension):** • As many as 2 out of 3 adults with diabetes have high blood pressure (***hypertension***). • Because of the risks of high blood pressure to people with diabetes, the American Diabetes Association and the National Institutes of Health recommend a lower blood pressure target than the general public (less than 130/80 mmHg). • Hypertension raises risk for heart attack, stroke, eye problems, and kidney disease. • Blood pressure can be controlled with lifestyle changes, such as diet and exercise, and medication.
Brain	Nervous	With information in the form of nerve impulses, the brain is able to monitor and regulate unconscious body processes, such as digestion and breathing and to coordinate most voluntary movements of your body.	**Dementia:** From large epidemiological studies, it has been demonstrated that both ***vascular*** and ***Alzheimer's dementia*** are more common in patients with type 2 diabetes. **Stroke:** • 2 out of 3 people with diabetes die from stroke or heart disease. • A stroke occurs when blood supply to part of your brain is interrupted and brain tissue is damaged, resulting in paralysis, problems with thinking or speaking, or emotional problems.
Eye	Nervous System	Your eyes are connected to your brain and are dependent upon the brain to interpret what we see. It consists of the cornea, iris, lens, macula, optic nerve, pupil, retina, and other structures.	**Blindness:** Most blindness in U.S. adults is caused by diabetes (***diabetic retinopathy)***. Diabetic retinopathy happens when diabetes damages the tiny blood vessels inside your retina, the light sensitive tissue at the back of the eye.
Kidneys	Urinary	The kidneys, a pair of dark red bean-shaped, fist-sized organs, make urine from waste products and excess water in the blood, and keep your blood composition constant (e.g. water, pH and salt).	**Kidney Disease:** • High blood sugar can overwork kidneys, causing them to stop working properly, and can result in excess sugar and proteins leaking into the urine. • When diagnosed later, kidney failure usually results.

Feet	Appendage (*contains structures from various different body systems*)	Your feet allow for mobility.	Nerve damage, as a result of high blood sugar, from diabetes can cause you to lose feeling in your feet. You may not feel a cut, a blister or a sore. Foot injuries such as these can cause ulcers and infections. Serious cases may even lead to amputation. Damage to the blood vessels can also mean that your feet do not get enough blood and oxygen. It is harder for your foot to heal, if you do get a sore or infection.
Pancreas	Digestive/ Endocrine	The function of the pancreas is to secrete enzymes (digest fats, proteins, and carbohydrates) and hormones (**insulin** and **glucagon**) that control blood sugar levels. Insulin lowers blood sugar by increasing the intake of glucose to cells (fat, muscle and liver cells). Glucagon increases blood sugar by triggering the liver to release glucose into the blood.	Sustained high blood sugar (***hyperglycemia***), occurring in all types of diabetes, increases blood fats. Constant exposure of the ***beta cells*** (insulin-producing cells in the pancreas) to blood fats is thought to prompt an inflammatory effect. Though not well understood, sustained inflammation appears to reduce insulin production (by the pancreas) and possibly destroy the insulin-producing beta cells completely.
Skin	Integumentary	Skin, the largest organ, is flat, pliable and tough, between 0.5 and 4m thick. Its function is to protect your body from damage, infection and drying out.	**Effect of Diabetes on Skin:** At least 33% of people with diabetes will have a skin disorder caused or affected by diabetes at some time in their lives, which is often the first sign of diabetes.
Lungs	Respiratory	Your lungs are a pair of large sponge-like organs that almost fill your chest cavity, and deliver oxygen to and remove carbon dioxide from your blood.	**Effect of Diabetes on the Lungs:** It has been shown that lung damage, caused by type 1 and 2 diabetes, is the result of ***diabetic microangiopathy*** (damage to small blood vessels).
Blood vessels	Cardiovascular	Blood vessels (arteries, veins and capillaries) carry blood to and from the body.	**Effect of Diabetes on Blood Vessels:** High blood glucose levels cause the endothelial cells lining the blood vessels to take in more glucose than normal. As a result, these cells form more *glycoproteins* on their surface than normal, and cause the basement membrane to grow thicker and weaker, causing them to bleed, leak protein, and slow the flow of blood through the body.

Stomach	Digestive	The function of the stomach, a J-shaped elastic organ, is storing food, breaking food down and mixing it with juices secreted by its lining.	**Gastroparesis:** • ***Gastroparesis*** is a type of ***neuropathy*** (nerve damage) in which food is delayed from leaving the stomach, due specifically to damage to the ***vagus nerve***, and is caused by long periods of high blood sugar. • Delayed digestion makes the management of diabetes more difficult. • It can be treated with insulin management, drugs, diet, or in severe cases, a feeding tube. • This disorder affects people with both type 1 and 2 diabetes.
Liver	Digestive	The liver (largest internal organ), a wedge-shaped, spongy organ, gets rid of toxins, regulates your blood sugar levels and to produces bile. The liver regulates blood sugar by responding to a hormone, **glucagon**, by breaking down glycogen to glucose in liver cells, and releasing the glucose to the blood. Liver storage cells store glucose and glycogen (as do muscle cells).	***Hemochromatosis***, an autosomal recessive inherited condition, characterized by elevated absorption of iron from the small intestine and excessive accumulation of iron in the liver and other tissues. Patients with untreated hemochromatosis develop progressive liver disease, ***cirrhosis*** (hardening of the liver), and diabetes and are at high risk for developing ***hepatocellular carcinoma*** (liver cancer). ***Note:*** *The liver can also convert amino acids (building blocks of proteins) into glucose (gluconeogenesis) and fat into ketones for energy when blood glucose is low.*
Bladder	Urinary	The bladder stores urine. When this organ stretches beyond a certain point, nerves in its wall send a message to your brain telling it that this organ is getting full and needs to be emptied.	**Effect of Diabetes on the Bladder:** • Diabetes can affect the nerves that control the bladder, making it difficult for a person to empty his or her bladder completely. • Incomplete emptying of the bladder can result in the growth of bacteria in the bladder and the tubes leading from it, eventually causing infection. • Without prompt examination and treatment by a doctor, the infection can reach the kidneys, causing pain, fever, and possibly kidney damage.

Muscle	Muscular-Skeletal	Muscle accounts for about half of a person's weight. There are 3 types of these in your body: voluntary, smooth and cardiac.	**Effect of Diabetes on Muscles:** • Research has shown that "known and newly diagnosed diabetic older men have significantly weaker muscle strength and higher odds of impaired physical function than those without diabetes". • From this study, there appears to be a relationship between raised glucose levels, weaker muscle strength, and impaired physical function.
Nerve	Nervous	1. Receive information from the sensory receptors, 2. Transfer and interpret impulses, and 3. Send impulses to the muscles and glands.	If you have diabetes, your blood sugar levels are too high. Over time, this can damage the covering on your nerves or the blood vessels that bring oxygen to your nerves. Damaged nerves may stop sending messages, or may send messages slowly or at the wrong times. This damage is called ***diabetic neuropathy***. ***What is Diabetic Neuropathy?*** • ***Diabetic neuropathy*** is a ***peripheral*** (near the surface) nerve disorder caused by diabetes or poor blood sugar control. • The most common types of diabetic neuropathy result in problems with sensation in the feet. It can develop slowly after many years of diabetes or may occur early in the disease. • The loss of sensation in the feet may also increase the possibility that foot injuries will go unnoticed and develop into ulcers or lesions that become infected, and can be associated with weakness in the foot muscles. • Diabetes can also affect the ***autonomic nerves*** that control blood pressure, the digestive tract, bladder function, and sexual organs. • Problems with the autonomic nerves may cause lightheadedness, indigestion, diarrhea or constipation, difficulty with bladder control, and impotence.
Small and large intestine	Digestive	The small intestine, an organ, is a five meter long narrow tube that functions in the chemical digestion of food and the absorption of nutrients into your blood. The large intestine, an organ, is a 1.5 meter-long tube that functions in converting food waste products into feces. It is the final part of your digestive tract.	Longstanding diabetes can diminish the function the ***enteric nerves*** to the small intestine, leading to abnormal motility, secretion, or absorption. This can lead to bacterial overgrowth syndromes, resulting in diarrhea and abdominal pain. Though limited information is available, it is known that ***enteric neuropathy*** may affect the nerves of the colon, decreasing in colon motility and resulting in constipation.