**POE #2: The Calcium Disruption**

**Topic**

Unit 2- Histology, Integumentary, Bone (Bones, Blood Calcium, Calcium and Muscle/Nerve Function)

The case study below has been simplified for the purposes of this introductory anatomy and physiology course. As you progress in your academic and professional careers you may learn more extensive details related to this scenario.

**Introduction to the Phenomenon**

*As you read through the scenario below underline specific facts and information you find important to the situation*

Sandy was abruptly awoken in the middle of the night due to extreme muscle cramping and spasming. She was also experiencing tingling and burning in her fingertips, toes, and lips. Due to the pain and muscle spasming, she was unable to drive herself to the hospital, so she called 911 for an ambulance. Upon arrival the medics immediately began running tests on Sandy to determine why she was experiencing these symptoms. After running some tests on her blood, vitals, and hormones, they determined she has hypoparathyroidism. This is a rare condition where the body produces abnormally low levels of parathyroid hormone (PTH), which is vital in maintaining blood calcium levels.

**Driving Question(s)**

Why would hypoparathyroidism cause muscle cramps, muscle spasms, and tingling/burning sensations within Sandy’s body?

**Initial Hypotheses/Predictions**

*In the box below, please provide your initial ideas about a possible answer to the driving question above.*

Answers will vary from student to student

Predictions and hypotheses should be scientifically based

Possible answers to the driving questions should be described in this box

**Relevant Data & Analysis Questions**

***ALL analysis questions are italicized in the pages below***

**Sandy’s Demographics & Health**

Gender: Female

Age: 34

Height: 5’6”

Weight: 127lbs.

Average Blood Pressure: 114/74

Average Resting HR: 72bpm

**Sandy’s Test Results (The night she called 911)**

Sandy- Denotes Sandy’s levels

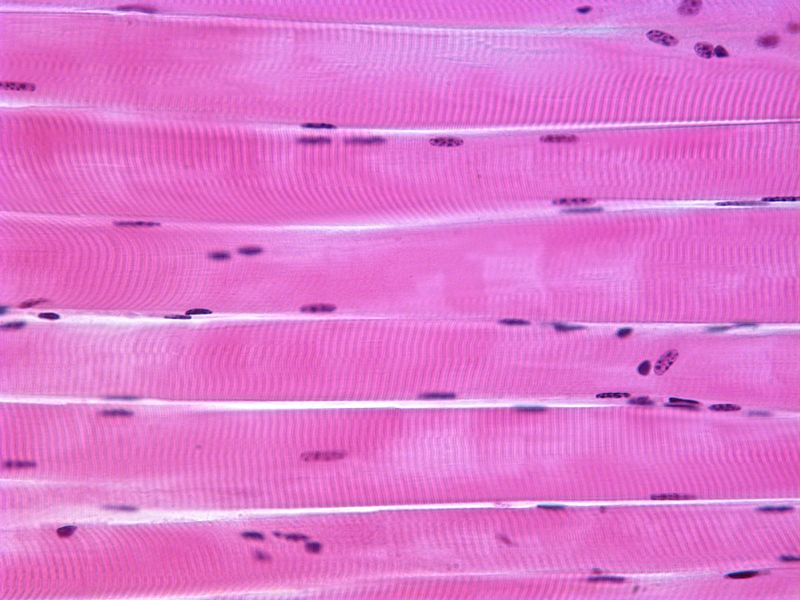
Normal- Are normal/average ranges for an adult female

|  |  |  |  |
| --- | --- | --- | --- |
| **Blood Work:** | **Calcium**  Sandy: 5mg/dL  Normal:  9-11mg/dL | **Parathyroid Hormone (PTH)**  Sandy: 5.5ng/L  Normal:  10-55ng/L | **Calcitonin**  Sandy: 50pg/ml  Normal: <5.0pg/ml |
| **Vitals:** | **Resting Heart Rate**  Sandy:  140bpm  Normal:  60-100bpm | **Blood Pressure**  Sandy:  130/82  Normal:  ≤120/80 | **Body Temperature**  Sandy:  99.4℉  Normal:  98.6℉ |

*Complete the table below to understand how Sandy’s vitals and bloodwork are abnormal.*

|  |  |  |  |
| --- | --- | --- | --- |
|  | For each health marker below write the normal average values for females/Sandy | Write Sandy’s values the night she called 911 | Are Sandy’s values higher or lower than normal (circle one) |
| Blood Pressure | 114/74 | 130/82 | HIGHER / LOWER |
| Resting Heart Rate | 72bpm | 140bpm | HIGHER / LOWER |
| Body Temperature | 98.6 | 99.4 | HIGHER / LOWER |
| Calcium | 9-11mg/dL | 5mg/dL | HIGHER / LOWER |
| PTH | 10-55ng/L | 5.5ng/L | HIGHER / LOWER |
| Calcitonin | <5.0pg/ml | 50pg/ml | HIGHER / LOWER |

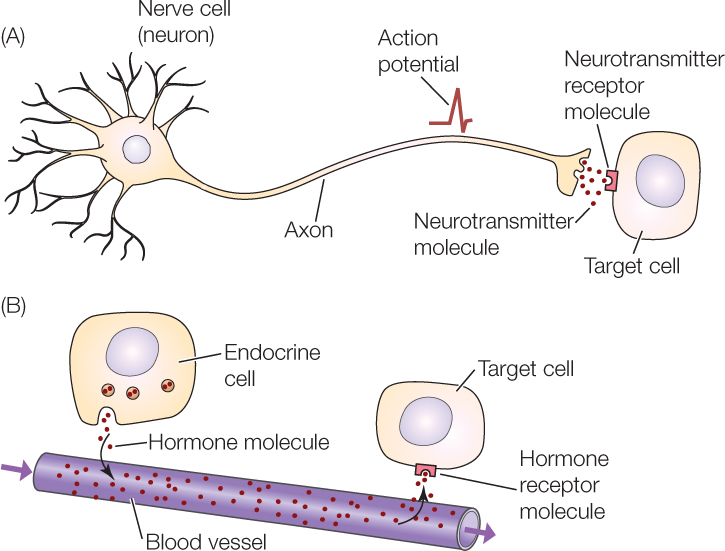
**Calcium’s Role in Muscle Contraction**

Skeletal Muscle Histology:

In muscle, Ca2+ binds to proteins located in the striations and initiates muscle contraction

Without Ca2+ the muscles are unable to contract because the proteins cannot interact

**Calcium’s Role in Nerve Function/Signaling**



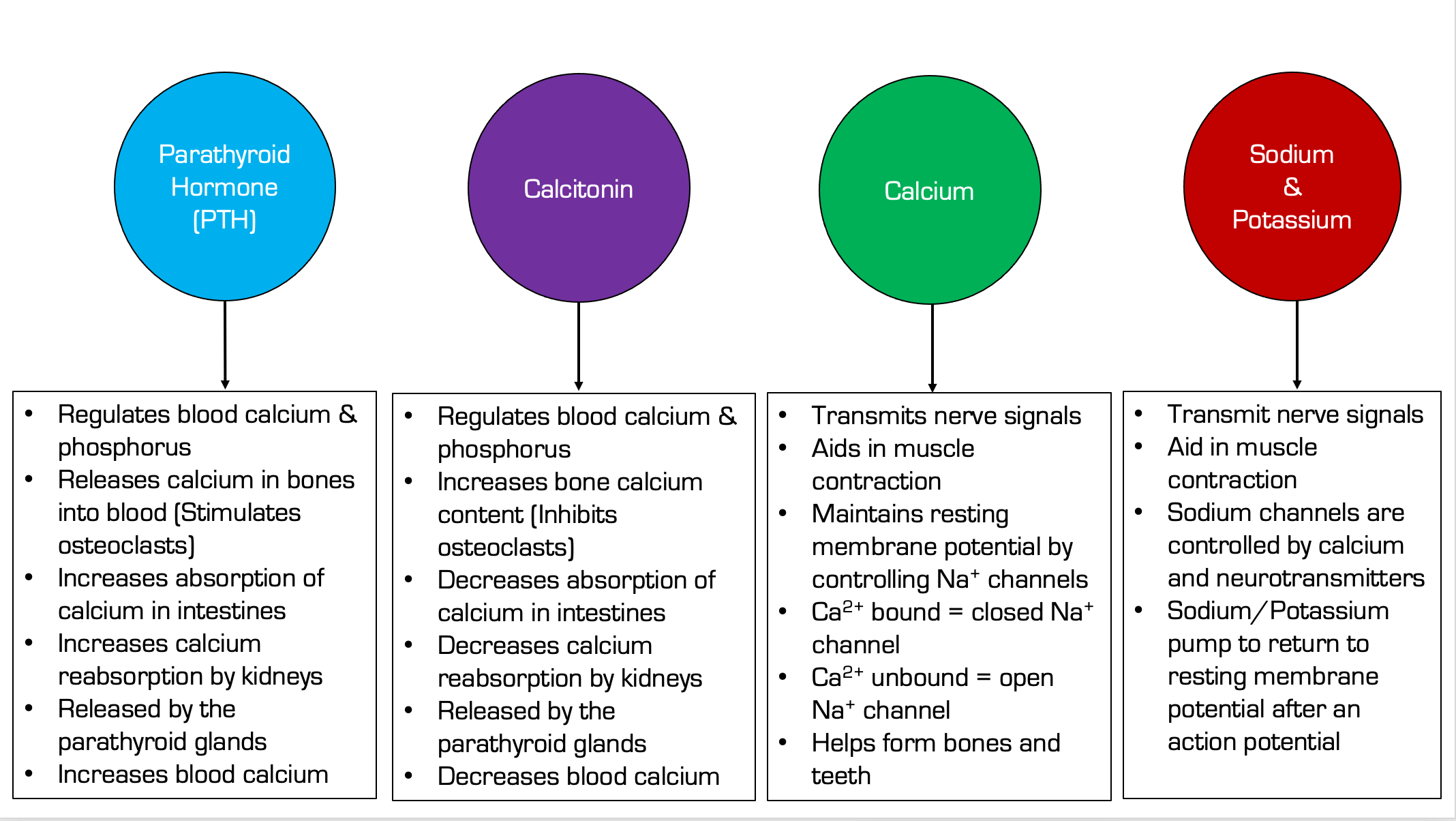
* In the nerve cell (neuron), Ca2+ stimulates the release of neurotransmitters
* Neurotransmitters stimulate other neurons or target cells (i.e. muscle cells)
* Stimulation of other neurons can lead to sensory or motor responses
* Stimulation of muscle cells can lead to muscle contractions
* Without Ca2+, target neurons and muscle cells wouldn’t receive important messages and signals

*Without calcium, would nerves and muscles be able to communicate? Why or Why Not?*

*No, because in order for nerves and muscles to communicate in the neuromuscular junction a neurotransmitter must be released from the neuron. Without calcium entering the neuron, the vesicles containing the neurotransmitters (in this case acetylcholine), would not receive the signal from calcium to bind to the membrane and release its contents. Calcium is responsible for signaling neurotransmitter vesicles to bind to the membrane and release their contents into the neuromuscular gap between the neuron and the muscle. When acetylcholine is released into this gap, it binds to receptors on the muscle membrane and allows other ion such as sodium and potassium to move in and out of the muscle cell to create an action potential for contraction.*

*Without calcium would muscles be able to contract properly? Why or Why Not?*

*No, because calcium plays a number of roles in proper muscle contractions. In order for muscles to contract they must first receive an action potential, which occurs when there is a change in the membrane potential due to an influx of sodium. Calcium is responsible for controlling certain sodium channels, so without calcium, these channels will not function properly and sodium will be able to freely leave and enter the cell causing sporadic and unintended action potentials. Also, calcium plays a role in the cross-bridge formation between actin and myosin, and this is the crucial part of a muscle contraction. The way a muscle contracts is through the binding and pulling of myosin on actin. In order for myosin to bind to actin, calcium must bind onto troponin to move tropomyosin off of the myosin binding sites on actin. So, without calcium this crossbridge formation will not occur and the muscle will not be able to contract.*

**Hormones & Ions Graphic**

*How would low levels of PTH affect the body?*

*Low levels of PTH would result in low blood calcium levels, because PTH is responsible for maintaining calcium levels in the blood. It works by activating osteoclasts in the bone, which break down the bone to release calcium into the blood. Also, low PTH would lead to an increase in calcium absorption in the kidneys and digestive tract, which would also lower blood calcium levels. Low blood calcium would lead to numerous abnormal symptoms such as the ones experienced by Sandy (i.e. muscle cramps and spasms and nerve pains)*

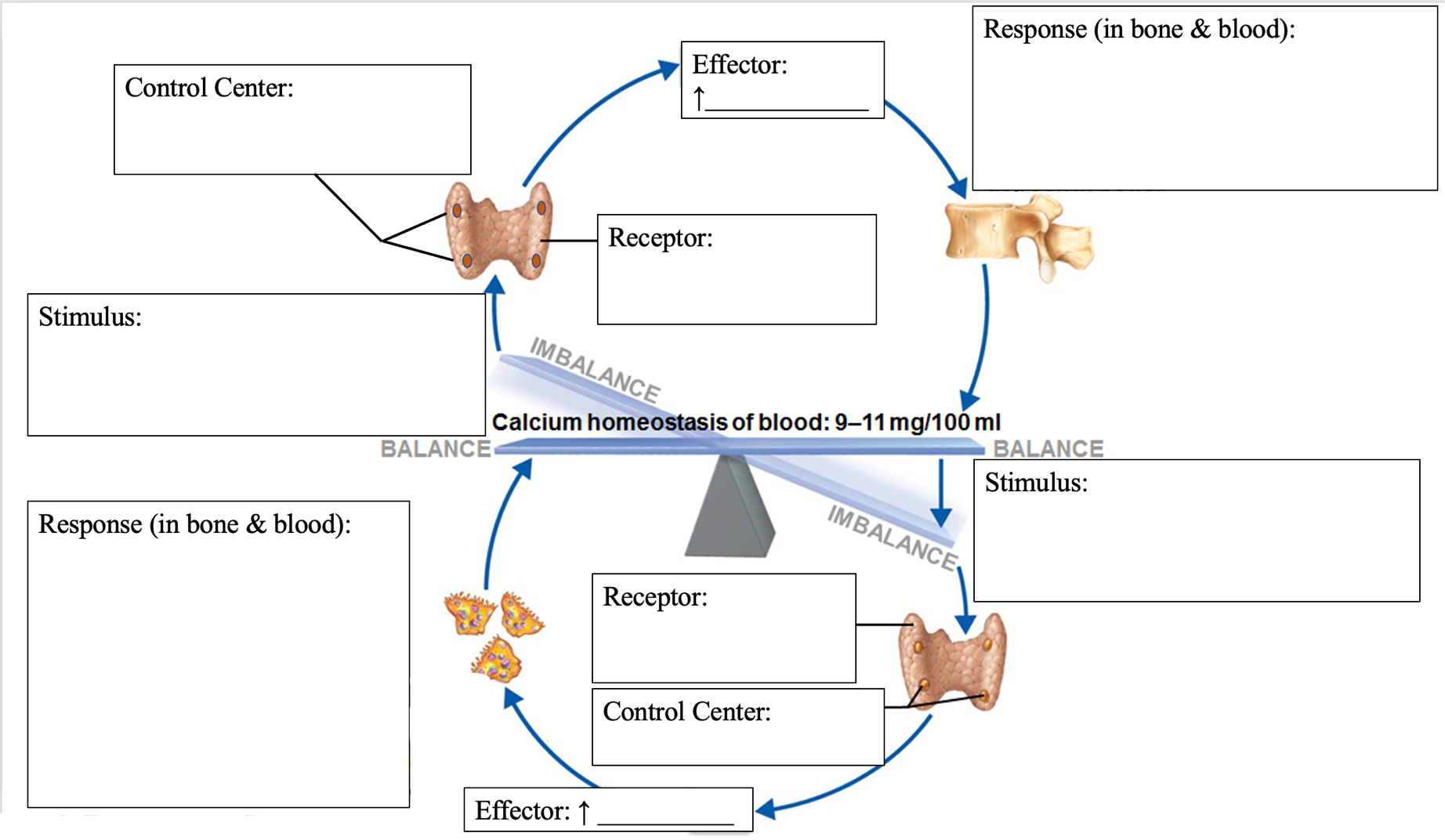
*How does calcium influence sodium channels? Would low blood calcium lead to more sodium or less sodium entering the muscle cell?*

*Calcium is responsible for controlling the opening and closing of sodium channels. When calcium is bound the sodium channel is closed, and when it is unbound the channel will remain open. Low calcium would lead to more sodium entering the cell, because the channels would be open and sodium could freely enter the cell moving from high to low concentration.*

*If resting membrane potential (the voltage across plasma membranes at rest) is increased by the movement of sodium down its concentration gradient into the cell, an action potential (electrical signal used in nerve communication and muscle contraction) will occur, what would happen if there was continual diffusion of sodium into the muscle cell?*

*If sodium continually enters the muscle cell then you would have constant muscle contractions, which would lead to cramping and spasming of muscles.*

*Complete the blood calcium homeostasis graphic below using your knowledge from lecture as well as the relevant data above:*



Parathyroid Glands

Pull calcium out of the blood and store in bones / Osteoblasts activated to build up bone/ Calcitonin stimulates calcium salt deposit in bone

Calcitonin

Pull calcium out of the bones and puts into the blood / Osteoclasts activated to breakdown bones and release calcium into the blood

PTH

Increased blood calcium levels/

Hypercalcemia

Decreased blood calcium levels/

Hypocalcemia

Thyroid Gland

Thyroid Gland

Parathyroid Glands

*How would the above blood calcium homeostasis be affected by Sandy’s hypoparathyroidism?*

*Sandy’s hypoparathyroidism would lead to a decrease in PTH, meaning that her body would be incapable of maintaining blood calcium homeostasis. Since PTH is responsible for increasing blood calcium levels, by activating osteoclasts and releasing calcium from the bones into the blood this would be affected by a reduction in PTH. Sandy’s condition would lead to overall reduced levels of blood calcium, which can become dangerous if the body is unable to return these levels to normal. Based on the above homeostasis graphic, Sandy would be experiencing the right side of the graphic where the stimulus is decreased blood calcium levels. In Sandy’s case the parathyroid glands sense a drop in blood calcium, but they are incapable of producing PTH, so the control center is unable to affect any change in blood calcium. Without PTH Sandy’s body cannot pull calcium out of the bones and release it into the blood to raise blood calcium levels back to normal.*

*How would low blood calcium affect bone growth? Would we expect there to be an increase or decrease in bone growth? Explain.*

*Low levels of blood calcium would lead to a decrease in bone growth and likely a decrease in bone density if there is a prolonged reduction in blood calcium. When blood calcium is low, the body responds by breaking down the bones to release calcium into the blood. Over time this break down of bone would lead to weaker and less dense bones. Also, if blood calcium levels are low, then the body will not favor bone growth, rather it will favor bone break down in order to maintain homeostasis of blood calcium. The body will favor bone breakdown over growth because it is sensing low blood calcium levels, and to adjust for this deficit it must rely on the calcium stored in the bones.*

*How could regular sun exposure and a calcium rich diet aid in preventing osteoporosis?*

*Regular sun exposure is important to provide the body with a sufficient amount of vitamin D, because UVB rays from the sun will stimulate vitamin D synthesis in the skin. Vitamin D is important, because it helps increase calcium absorption which is important for bone health. If a person is eating a diet rich in calcium, and simultaneously getting adequate sun exposure, they will be able to prevent osteoporosis by promoting increased vitamin D synthesis, increased calcium absorption, and achieving overall bone growth, strength, and health.*

**Observations**

*After examining the data and answering the analysis questions above, describe interesting observations and patterns you believe are relevant to explaining the phenomenon. You can include both textual and visual observations in order to help organize the data from above. (Include at least 10 important pieces of data and evidence that will aid in your final explanation of the phenomenon below)*

Observations will vary from student to student

Example Observations Listed Below:

* Ions play a major role in bodily functions and health
* Sodium, potassium, and calcium are all important for muscle contraction and function
* Nerve and muscle impulses and signaling are largely controlled by ions
* Calcium plays a role in bone and teeth health as well and nerve and muscle function
* Calcium is required to transmit nerve signals throughout the body
* Calcium also plays a role within neuromuscular junctions by signaling the release of NTs that can attach to receptors on the muscle cells and initiate action potentials
* Calcium controls other ion channels (i.e. sodium), and when there are inappropriate levels of calcium in the blood this can lead to random opening of sodium channels leading to involuntary contractions and spasms in the muscles (i.e. cramps/twitching)
* Calcium also aids in allowing crossbridge formation between actin and myosin
* Hormones are important for controlling and maintaining bodily functions
* Homeostasis of different bodily functions is controlled by various hormones
* Maintaining blood calcium is crucial for normal function
* Homeostasis of blood calcium is controlled by the thyroid and parathyroid glands as well as PTH and calcitonin
* PTH is responsible for raising blood calcium levels
* Calcitonin is responsible for lowering blood calcium levels
* Bone remodeling is also under the control of hormones such as PTH, calcitonin, and growth hormone
* In order to contract, muscles and send signals down nerves it is important to have the proper ions available in their optimal concentrations
* Specific data related to Sandy’s condition:
  + Blood calcium level: 5mg/dL (Very low due to a lack of PTH in the body)
  + Hormone levels:
    - Low PTH (5.5ng/L) indicative of hypoparathyroidism
    - Elevated Calcitonin (50pg/ml) increasing activity of osteoblasts and decreasing blood Ca levels
  + Vital are all elevated due to the downstream effects of low calcium in the blood:
    - HR 140bpm, BP 130/82, Temp 99.4
    - Elevated HR because the heart is trying to pump blood around body faster to deliver Ca2+ to the brain, nerves, and muscles to aid in normal function because the Ca2+levels are so low
    - BP then increases due to an increase in HR
    - Rise in body temperature likely due to the increased HR, BP, and the muscle contractions and spasms
    - Increased respiration rate due to muscle spasms and nerve pains because of the low Ca2+

**Explanation**

*Based on the data and analysis questions above, please provide an answer to the driving question(s) in the box below. Remember to include data from above as evidence, important ideas from previous units, and the concept of homeostasis in your response.*

**Driving Question(s)**

*Why would hypoparathyroidism cause muscle cramps, muscle spasms, and tingling/burning sensations within Sandy’s body? Discuss how blood calcium homeostasis and muscle/nerve function are affected by Sandy’s condition.*

Explanations will vary from student to student

A detailed example explanation is provided below:

Based on the phenomenon and data above it is evident that Sandy has a condition called hypoparathyroidism, which affects her blood calcium levels due to the dysfunction of the parathyroid glands and their associated hormones. Sandy’s normal health stats were provided in the data section, and based on this information we know that Sandy is a 36-year-old female with a normal resting HR (72bpm) and BP (114/74). Also, her height (5’6”) and weight (127lbs) indicate a healthy range. Comparing Sandy’s normal health stats to her test results on the night she called the ambulance, we can see several abnormal measures indicating she is in a state of distress and dysfunction. Starting with Sandy’s blood work it is evident that her blood calcium levels are low at 5mg/dL compared to the normal range of 9-11mg/dL, this is already one indication of hypoparathyroidism. Then looking at her hormones it is evident that PTH levels are extremely low at 5.5ng/L compared to the normal range of 10-55ng/L, and calcitonin levels are quite high at 50pg/ml compared to the normal level <5.0pg/ml. These two hormones are key indicators of hypoparathyroidism, because this condition means the body is not producing PTH, and that calcitonin is then over active. Both of these abnormal hormone levels would also be an indication of low blood calcium, and ultimately explain all of Sandy’s symptoms.

In the phenomenon it was stated that Sandy was experiencing muscle spasming, cramping, and nerve pains. These symptoms align with the issues sandy was experiencing on an ionic and hormonal level. For example, in the data and analysis question section, there was a graphic explaining ion functions and hormone functions. Based on these graphics we know that sodium, potassium, and calcium all play a role in muscle contraction and transmission of nerve signals. So in Sandy’s case her low levels of calcium in the blood would lead to muscle spasms and cramps due to improper action potential signaling, ion channel opening, and cross bridge formation. Also due to Sandy’s low levels of PTH and high calcitonin levels we would expect her calcium levels to be out of balance, and ultimately affect her blood calcium homeostasis. If blood calcium levels are not maintained at a level of 9-11mg/dL this can cause downstream problems in the bones, muscles, and nerves. Normal blood calcium homeostasis works by detecting a change in calcium levels and appropriately responding to correct this change. For example, if there is a decrease in blood calcium below normal levels, the parathyroid glands will detect this change, they will then release PTH, which will travel to the bones to activate osteoclasts and release calcium from the bones to put back into the blood and raise levels. If there are high levels of blood calcium above the normal range, the parathyroid glands will detect this change, they will then release calcitonin, which will activate osteoblasts to sequester calcium from the blood and store it in the bones. This is generally how blood calcium homeostasis is maintained in the body.

*Explanation Continued:*

In Sandy’s case her control center, the parathyroid glands, are dysfunctional and ultimately are incapable of releasing PTH to bring low blood calcium levels back to normal. This will then lead to low calcium in the body, which affects the nerves, muscles, and bones. Low calcium will affect the neuromuscular junction because without calcium the nerves can’t release their neurotransmitters. Without NTs the nerve can’t signal the muscles to contract. Low calcium can also lead to improper sodium channel control on the muscles, so if sodium is able to move into the cell randomly this would lead to muscle spasms and cramping, because involuntary contractions would take place. Ultimately the interplay between the parathyroid glands, hormones such as PTH and calcitonin, and ions such as calcium and sodium is what allows the body to maintain homeostasis and normal function. If certain aspects of this interplay are disrupted then homeostasis will be affected, and normal bodily functions will not take place.