CVS

PHYSIOLOGY

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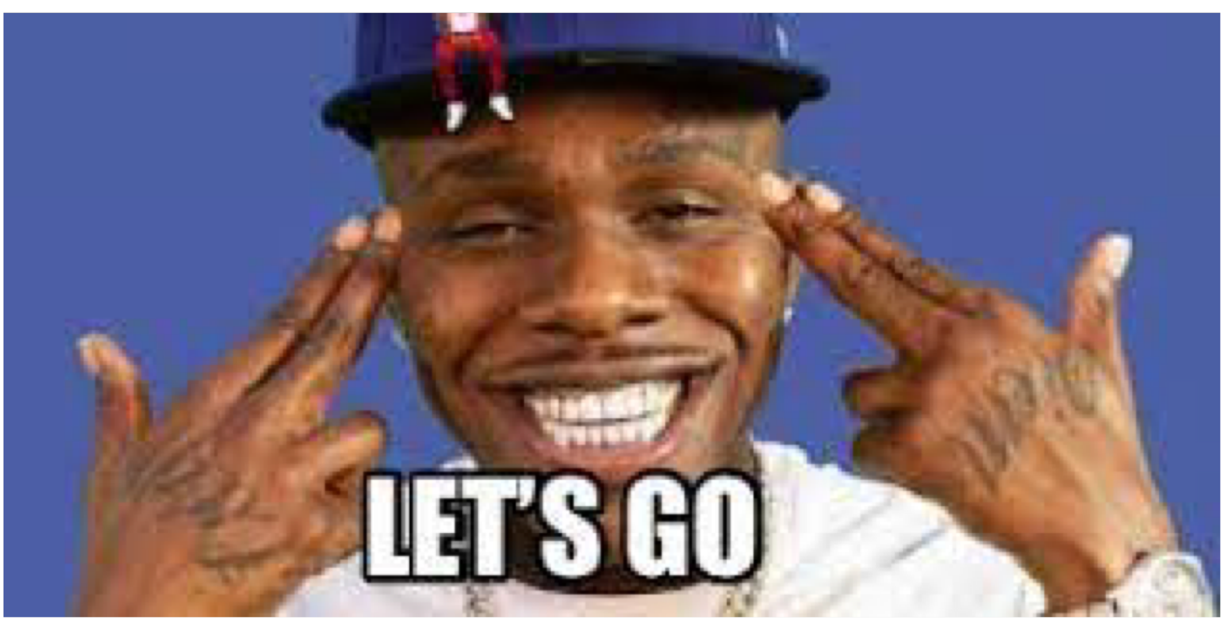
Let’s start with the vascular distensibility

*Vascular Distensibility is the fractional increase in volume for each mmHg rise in pressure
*Veins are 8 times more distensible than arteries
*Pulmonary arteries are relatively distensible
*Vascular Distensibility = Increase in volume /(Increase in pressure x Original volume)

Vascular Capacitance
*Vascular capacitance is the total quantity of blood that can be stored in a given portion of the circulation for each mmHg.
*Capacitance = Distensibility x volume
*The capacitance of veins is 24 times that of arteries.
*Vascular compliance =Increase in volume /Increase in pressure

Volume-pressure Relationships in Circulation
*Any given change in volume within the arterial tree results in larger increases in pressure than in veins.
*When veins are constricted, large quantities of blood are transferred to the heart, thereby increasing cardiac output.

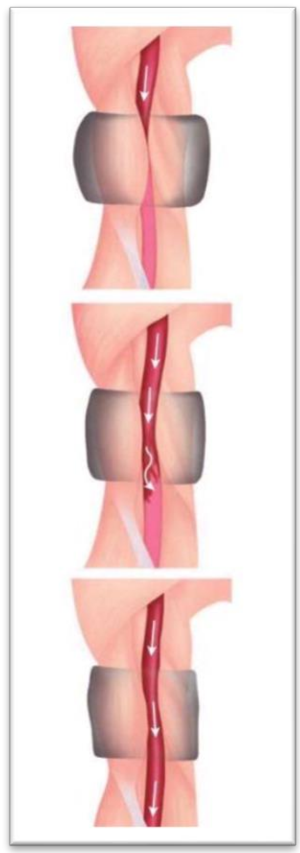
And now let’s start with the fun part 😈



❖ Measuring blood pressure:

- Blood pressure is measured indirectly with a sphygmomanometer. An externally applied inflatable (capable of being filled with air) cuff is attached to a pressure gauge. When the cuff is wrapped around the upper arm and then inflated with air, the pressure of the cuff is transmitted to the underlying antecubital (brachial) artery. The pressure is balanced in the cuff against the pressure in the artery.
  - When cuff pressure is greater than the pressure in the artery, the artery is pinched to close so that no blood flows through it.
  - When blood pressure is greater than cuff pressure, the vessel opens and blood flows through.

❖ Blood pressure is determined by placing a stethoscope over the brachial artery, at the bend of the elbow, and just below the cuff. No sound can be detected when blood is not flowing through the vessel and when blood is flowing in the normal, smooth laminar flow. Turbulent blood flow, in contrast, creates vibrations that can be heard, known as **Korotkoff sounds.**



systolic pressure

1. When cuff pressure is greater than 120 mmHg and exceeds blood pressure, no blood flows through the vessel and no sound can be heard.
2. When cuff pressure is between 120 and 80 mmHg, blood flow through the vessel is turbulent. *The highest cuff pressure at which the first sound can be heard indicates the systolic pressure*, as the cuff pressure continues to fall, blood intermittently passes through the artery and produce sounds.
3. When cuff pressure is less than 80 mmHg and it's now below blood pressure, blood flows through the vessel in a smooth, laminar fashion. *The highest cuff pressure at which the last sound can be detected indicates the diastolic pressure.* No sound is heard after that because of the uninterrupted, smooth, laminar flow.

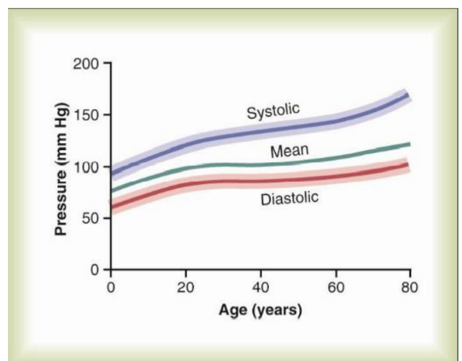
Pulse pressure: the pulse that can be felt in an artery lying close to the surface on the skin as a result of the difference between systolic and diastolic pressures. When blood pressure is 120/80, pulse pressure is 120-80= 40 mmHg.

Mean arterial pressure (MAP) is the average pressure driving blood forward into tissues throughout the cardiac cycle. MAP is not the halfway value between systolic and diastolic pressure, the reason is that arterial pressure remains closer to diastolic than to systolic pressure for a longer portion of each cardiac cycle. About two thirds of the cardiac cycle is spent in diastole and only one third in systole. As an analogy, if a car travelled 80 Km/h for 40 minutes and 120 Km/h for 20 minutes, its average speed would be 93 Km/h, not 100 km/h.

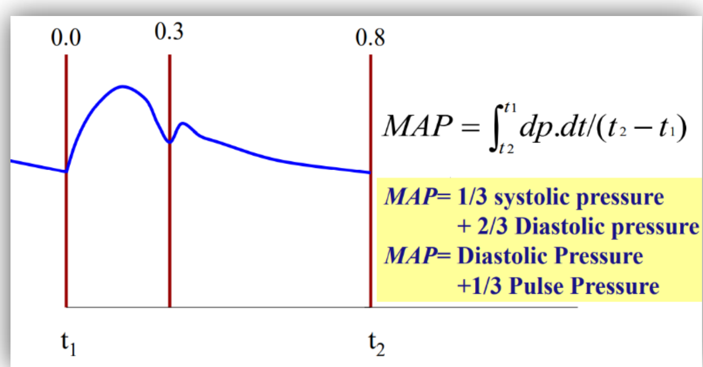
MAP can be determined using the following formula:

Mean arterial pressure = 2/3 diastolic pressure + 1/3 systolic pressure

Or = diastolic pressure + 1/3 pulse pressure



- You can notice from the adjacent figure that the MAP is closer to the diastolic pressure than the systolic pressure.
- MAP represents the area under the curve shown below. It is equal to the change of pressure over the period of time during which that change happened. One can notice that the diastolic period (0.5sec) contributes more to the area under the curve than systolic period (0.3sec), and thus contributes more in determining the MAP.



❖ Blood Pressure Regulation:

Mean blood pressure is the driving force of blood flow through the circulation and thus is the blood pressure that is monitored and regulated in the body, **not** the arterial systolic nor the diastolic or pulse pressure.

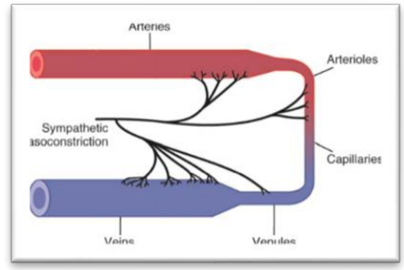
MAP = CO x TPR

= [SV x HR] x TPR

Blood pressure is regulated by controlling cardiac output (SV and/or HR), and total peripheral resistance.

- Arterial Pressure can be increased by:
  - Constricting almost all arterioles of the body which increases total peripheral resistance → ↓arteriolar radius ↑↑ TPR.
  - Constricting large vessels of the circulation thereby increasing venous return and cardiac output → ↑venous return ↑EDV ↑SV (Frank-starling law).
  - Directly increasing cardiac output by increasing heart rate and contractility → at the same EDV, SV is increased by lowering ESV.
- Autonomic Nervous System:
  - Sympathetic nervous system is important in control of circulation since it is the only autonomic division that supplies blood vessels <u>except capillaries (which lack the muscular layer), precapillary sphincters and some metarterioles.</u> Innervation of small arteries and arterioles allows sympathetic nerves to increase vascular resistance. Large veins and the heart are also sympathetically innervated.
    → dominant in controlling contractility of the heart and TPR.
  - Parasympathetic nervous system is important in regulating heart function → dominant in controlling HR via the vagus nerve.
  - If all autonomic nerves to the heart were blocked, the HR would increase, and the contractility would decrease.

- In the case of organs innervated only by sympathetic fibers like blood vessels, regulation is accomplished by increasing or decreasing the firing rate (frequency of basal rate) above or below the tonic level in these fibers, resulting in vasodilation (lower tone) or vasoconstriction (higher tone).



- This ongoing basal rate means that there is always some sort of discharge, this is important to have positive and negative control over the basal tone. If this tone is absent, only positive control would be possible.

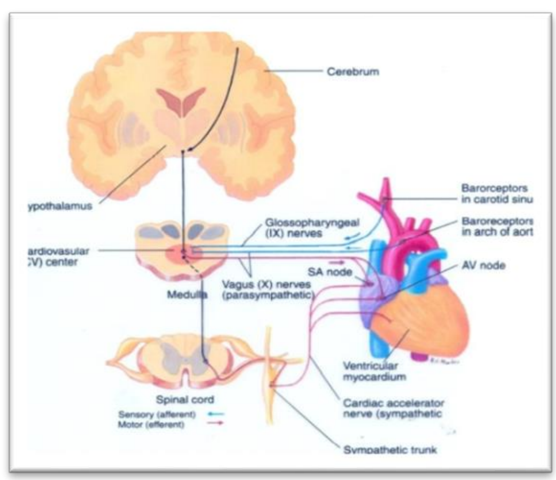
Short term regulation of BP:

- The baroreceptor reflex is an important short-term mechanism for regulating blood pressure. Any change in MAP triggers an autonomically mediated baroreceptor or presso-receptors (High pressure) reflex that influences the heart and blood vessels to adjust CO and TPR in order to restore normal blood pressure.

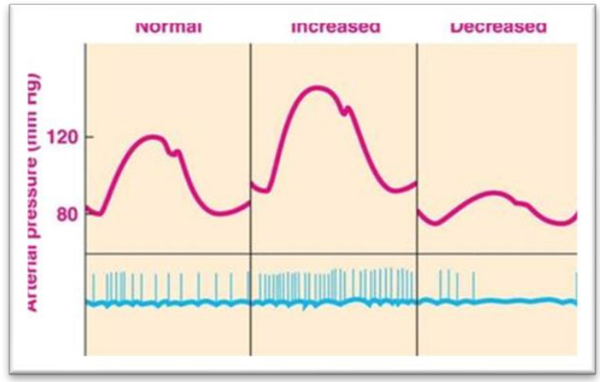
Like any reflex, the baroreceptor reflex includes:

1. Receptor.
2. Afferent pathway.
3. Integrating center (cardiovascular center in the brain).
4. Efferent pathway.
5. Effector organs (heart and vessels in this situation).

- The most important receptors involved in moment-to-moment regulation of blood pressure are the carotid sinus (through a branch of the ninth cranial nerve, the glossopharyngeal nerve known as Hering's nerve) and the aortic arch baroreceptors (through the tenth cranial nerve, the vagus nerve). These are stretch or mechanoreceptors sensitive to changes in blood pressure. Their location is strategic (close to the heart) to provide critical information about BP.



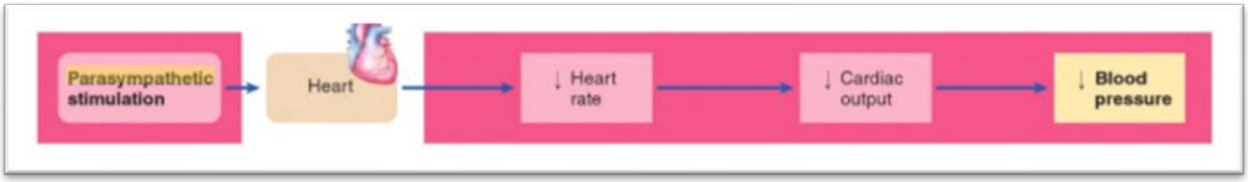
- The baroreceptors continuously generate action potentials in response to the ongoing pressure within arteries. When arterial pressure increases, the receptor potential increases, thus increasing the rate of firing in the afferent neuron. Conversely, a decrease in MAP slows the rate of firing generated in the afferent neurons.



- The cardiovascular center in the medulla receives the afferent impulses about the state of MAP. The efferent pathway is the autonomic nervous center, it alters the ratio between sympathetic and parasympathetic activity to the heart and blood vessels.
- The cardiovascular is divided into cardio center and vasomotor center. The cardiac center is further subdivided into cardio-acceleratory and cardio-inhibitory. The vasomotor center is subdivided into vasoconstrictor area, vasodilator area, and sensory area.
- The sensory area is the area that receives the afferent impulses and send messages to the vasoconstrictor and vasodilator areas. The vasoconstrictor area is the only area that sends downward (efferent neurons), through the sympathetic system. The vasodilator area acts indirectly over the vasoconstrictor area and suppresses its activity instead of directly sending efferent neurons (because the parasympathetic system does not innervate the vessels).
- Now, let's fit all the pieces of the baroreceptor reflex together by tracing the reflex activity that compensates for changes in BP.
  a. Elevation of blood pressure: if for any reason the MAP rises above normal, the carotid sinus and aortic arch baroreceptors increase the rate of firing in their afferent neuron, the cardiovascular center responds by decreasing sympathetic activity and increasing parasympathetic activity.
     1. The vasodilator area inhibits the vasoconstrictor area →arteriolar dilation → ↓TPR.

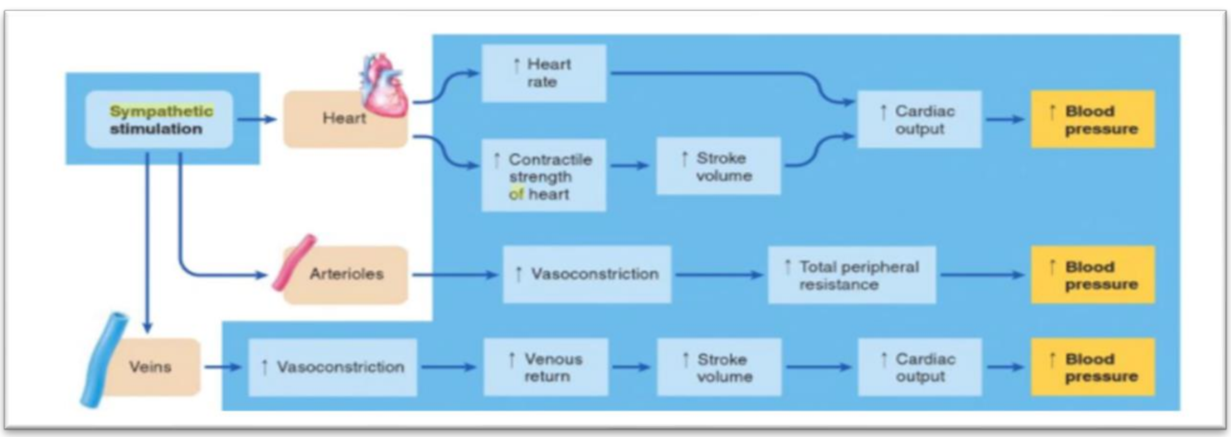
2. The lowered sympathetic tone also induces venous vasodilation which in turn decreases the venous return → ↓CO.
3. Inhibition of the cardio-acceleratory center and activation of the cardio-inhibitory center → Decreased contractility ↓SV, ↓HR.

The overall effect is a decrease in both the TPR and CO and thus blood pressure is decreased to normal levels.

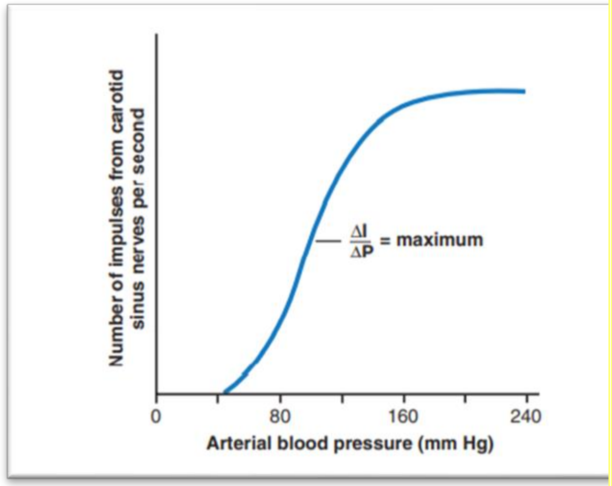


b. Conversely, when blood pressure falls below normal, baroreceptor firing rate decreases, inducing the cardiovascular center to increase sympathetic cardiac and vasoconstrictor activity while decreasing parasympathetic output.
   1. The vasoconstrictor area is activated → arteriolar constriction ↑TPR.
   2. Increased venous vasoconstriction → ↑MSFP →↑venous return → ↑ EDV → ↑SV → ↑CO according to Frank-Starling law.
   3. Activation of cardio-acceleratory center and inhibition of the cardio-inhibitory center → ↑HR and ↑ contractility → ↑SV.

   The overall effect is an increase in both the TPR and CO and thus blood pressure is raised back to normal levels.

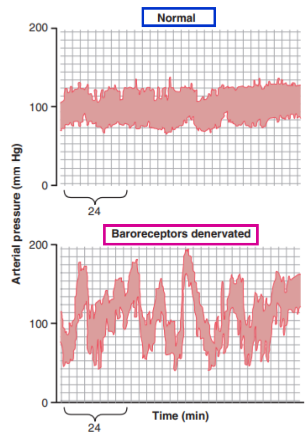


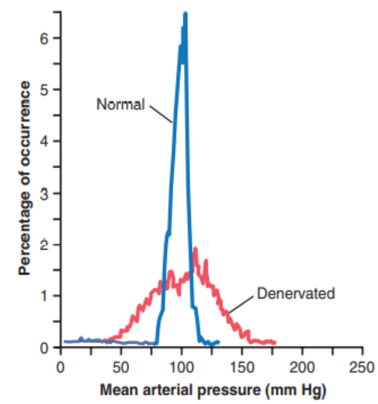
- ΔI is the number of impulses fired by baroreceptors at different levels of arterial pressure. ΔP is the change in arterial blood pressure in mm Hg.



  - Maximal sensitivity (highest slope) occurs near the normal mean arterial pressure which is 100 mmHg; therefore, very small changes in arterial pressure around this "set-point" dramatically alters receptor firing so that autonomic control can be altered in such a way that the arterial pressure remains very near to the set-point. Stated differently, a small increase in BP above 100 mmHg would increase the firing rate of baroreceptors sharply, restoring BP back to normal. Also, a small decrease of BP below 100 mmHg would result in a huge decrease in the firing rate of baroreceptors, raising BP back towards the normal "set-point". The baroreceptors are called "pressure buffer system" because they resist or oppose any changes in BP above or below the normal value.
  - Note that the baroreceptors are not stimulated at all by pressures between 0 to 60 mm Hg. And when BP increases to values much higher than the normal MAP, minimal changes in the firing rate are observed.
  - Baroreceptors adapt or 'reset' in response to maintained changes in pressure: It is important to note that baroreceptors adapt to sustained changes in arterial pressure. Therefore, baroreceptors play a crucial role in the short-term control of MAP but no role in the long-term control of blood pressure (the long-term regulation of arterial pressure requires activation of other mechanisms).
- When a person moves from lying down to standing up, especially after prolonged bed rest, pooling of blood in the leg veins due to gravity will take place and it reduces venous return, decreasing SV and thus CO and blood pressure. This fall in blood pressure is normally detected by the baroreceptors, which initiate immediate compensatory responses to restore BP to its proper level. The opposite happens when a standing person rests into a supine position.

- In older people, due to atherosclerotic changes, the arteries become rigid and the baroreceptors are less responsive to stretch. Thus, this reflex is temporarily lost or reduced. The best advice for these people is to stand up slowly in order to give time for the baroreceptors to respond properly.
- The adjacent figures compare the variation in BP in normal innervated baroreceptors and denervated ones (in which baroreceptor nerves from both the carotid sinuses and the aorta are removed).





- When the baroreceptors were functioning normally, the mean arterial pressure remained within a narrow range. Conversely, extreme variability of blood pressure is observed in the absence of innervation.