Experienced clinicians have always been able to feel abnormalities in the pulse which were related to high or low pressure, but routine measurement of arterial pressure did not start until the early 1900s.

This device, from 1895, is typical of early attempts to measure systolic and diastolic pressures. (It almost worked).

The structure of all blood vessels follows the same basic plan. Below is a section a small artery (about 1mm ID) showing the 3 layers.

Outer layer, the adventitia, is made up of collagen fibres and sometimes elastic fibres.

Middle layer, the media, consists of smooth muscle and nerves, and sometimes elastic fibres. (There is no media in capillaries.)

Inner layer, the intima, is a single layer of endothelial cells. It is sometimes called "the endothelium".

Cardiac output
5 l/min

Lymph flow
150 ml/hour
0.05% of CO

The diagram implies that blood vessels have a parasympathetic vasodilator innervation.

In fact, only a few vessels in specialised areas have this, as it says in the text. (Salivary and other exocrine glands, brain, facial skin, parts of the GI tract, genitals).

Most vessels have only sympathetic vasoconstrictor nerves.

Nerves to blood vessels  Very misleading diagram in Boron, figure 23-5
Arteries

The relative thickness of the wall is greatest in the smallest arteries (the arterioles).

The large arteries, which contain blood at the highest pressure, have the greatest amount of collagen and elastic fibres.

In small arteries smooth muscle is more important. Contraction or relaxation of the smooth muscle in small arteries and arterioles changes artery diameter and is used to regulate blood flow and pressure.

Capillaries

Capillaries have a very simple structure.

They consist of a single layer of endothelial cells.

Veins

Veins have thinner walls than arteries, and the blood pressure in them is lower.

The smallest veins are similar to capillaries with the addition of a small amount of muscle.

Larger veins have much thinner walls than arteries of the same size.

Distribution of blood in the circulation

<table>
<thead>
<tr>
<th>Part</th>
<th>% of blood volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left heart</td>
<td>3.5</td>
</tr>
<tr>
<td>Arteries</td>
<td>8</td>
</tr>
<tr>
<td>Arterioles</td>
<td>7</td>
</tr>
<tr>
<td>Capillaries</td>
<td>5</td>
</tr>
<tr>
<td>Venules</td>
<td>25</td>
</tr>
<tr>
<td>Veins</td>
<td>39</td>
</tr>
<tr>
<td>Right heart</td>
<td>3.5</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>3</td>
</tr>
<tr>
<td>Lung Capillaries</td>
<td>2</td>
</tr>
<tr>
<td>Pulmonary vein</td>
<td>4</td>
</tr>
</tbody>
</table>

87.5% in systemic circulation

12.5% in pulmonary circulation
Tissues need adequate blood flow...

To supply nutrients and remove waste. Flow depends on pressure difference (arterial - venous) across the tissue or organ and resistance.

\[
\text{Flow (litres/min)} = \frac{\Delta P \text{ (mmHg)}}{\text{Resistance (mmHg.min.l}^{-1})}
\]

In the body control systems try to keep a constant pressure, and the flow is regulated by resistance adjustments at the level of individual organs or tissues.

You might expect most of the resistance to be in the capillaries, because they have the smallest diameter. An individual capillary does have a higher resistance than an arteriole, but the resistance offered by all capillaries combined is very low because there are so many of them in parallel.

Arteries 1mm diam
- total in body = 8000
- total cross section area = 63 cm²

Arterioles 30µm diam
- total in body = 20,000,000
- total cross section area = 141 cm²

Capillaries 6µm diam
- total open in body = 10,000,000,000
- total cross section area = 2827 cm²

Blood pressure is pulsatile. The maximum pressure is known as the systolic pressure. The minimum is the diastolic pressure, and the difference between the two is the pulse pressure.

The shape of the pressure transients varies in different regions of the circulation, due to the interaction between the elasticity of the arterial walls and the viscosity and momentum of the blood. Pulse pressure is greater in large arteries than in the aorta, but mean pressure is lower.
For delivering blood to tissues, it’s mean pressure that counts. The mean pressure is not simply the level half way between diastolic and systolic, because of the complex shape of the pressure wave. Think of it as:
• the mean of a large number of readings taken at very short intervals
• the level around which there are equal areas above and below.

Approximately, mean BP = diastolic + 0.4(pulse pressure)

Everything so far applies to a person lying down.

A person standing has a large pressure variation due to the effects of gravity.
The pressures quoted earlier would be the pressures measured at the level of the heart when standing or sitting.
In a normal healthy person this would be the same as the pressures when lying down.

Normally, systemic blood pressure is controlled by a series of interacting homeostatic feedback mechanisms.

To control a physiological variable, there must be:
• receptors
• an integrating centre
• effectors

These are the basic components involved in the neural control of blood pressure.
(There are also hormonal controls, but I’m not going to talk about those.)
Carotid sinus baroreceptors respond to increased pressure in the carotid sinus. In experimental situations using steady pressures, the firing rate in the carotid sinus nerve increases as pressure is increased over the physiological range.

The receptors respond more strongly on average to pulsatile pressures when the mean pressure is low. The integrating centres in the medulla also respond more strongly to bursts than to continuous activity. (The situation is similar in many other physiological control systems.)

Specific regions of the medulla are concerned with both cardiovascular and respiratory control. (Cardiovascular areas coloured, details not important).

In from carotid sinus receptors

Parasympathetic out (vagus)

Sympathetic out

Effectors

ARTERIAL PRESSURE

CAROTID SINUS NERVE IMPULSES

VAGUS NERVE IMPULSES

Sympathetic cardiac nerve

Sympathetic vasconstrictor nerves

Normal
The heart is controlled by both sympathetic and parasympathetic nerves. Both are firing all the time ("Normal" panel, centre).

Parasympathetic (vagus) activity slows the heart. Sympathetic activity increases heart rate and force of contraction.

Cardiac Output = rate x stroke volume. BP = CO x resistance.

In practice, the body uses mainly changes in total peripheral resistance to fine-tune the arterial pressure.

Arteries and arterioles receive sympathetic vasoconstrictor nerves. They are always active, so their firing rate can be increased or decreased to increase or decrease peripheral resistance.

There are also sympathetic nerves supplying the veins. Like the nerves supplying arteries, they are tonically active vasoconstrictor nerves.

Unlike the arteries, veins do not contribute significantly to the resistance. Constriction of veins reduces the volume of blood in the veins, shifting it to some other region of the circulation. This may be important in blood pressure regulation during postural changes, for example.
Changes that occur when you go from lying down to standing up.

Central venous pressure falls

because gravity increases venous pressure in the lower body, distending veins in the legs and abdomen.

Central venous pressure is the force that moves blood into the right side of the heart.

Blood enters the heart at a lower rate ("reduced venous return") so cardiac output falls.

BP = CO x resistance, so BP falls.

Normally the fall is very small and immediately causes a variety of compensatory actions.

Compensatory responses on standing

Vasoconstriction in the legs and abdomen especially in the veins.

Constriction of the veins reduces the volume of blood there and increases venous return.

There may also be a small increase in sympathetic activity to the heart, and an increase in heart rate.

Cardiac output rises back to normal.

Constriction of arterioles increases peripheral resistance.

BP rises towards normal.

In this experiment the subject was fastened to a table which can be tilted.

In a normal person there is no significant difference between blood pressure lying and standing.

But there are differences in other parameters. Compared to lying down, when standing there is:

- lower pulmonary blood volume
- lower central venous pressure
- lower cardiac output
- greater lower limb blood volume
- increased total peripheral resistance (mainly due to lower limb and abdomen resistance)
- decreased lower limb blood flow
In a person with seriously decreased blood volume:

Constriction of veins in the lower body cannot return central venous pressure to normal, so venous return and cardiac output fall.

Blood pressure falls, and the baroreceptor reflex responses increase to try to restore it.

- Heart rate increases
- Vasoconstriction is more widespread than normal, in an attempt to increase peripheral resistance.
  - Renal vasoconstriction reduces renal blood flow to low levels.
  - Vasoconstriction in the skin makes the person look pale.

Everything so far has been for a person standing still.

In someone walking around, venous return is facilitated by the active muscles pressing on the veins and squeezing the blood along. Blood goes towards the heart because the veins contain valves.

It’s known as the “muscle pump” and it’s in all the books, eg Boron page 586. (2nd ed 2009)