are found primarily in the heart, and b_2 receptors are found in the bronchioles and in other sites that have b-mediated functions. In many tissues, the response that occurs is determined by the presence of a particular receptor type, which can vary from tissue to tissue. For example, in vascular smooth muscle that has a_1 receptors, sympathetic stimulation produces vasoconstriction; similar stimulation produces vasodilatation in other vessels that have b_2 receptors.

The role of the ANS in control of blood pressure is only beginning to be understood. For example, central a_2-adrenergic receptors are known to inhibit sympathetic outflow from the brain. Several antihypertensive medications exert their effect at this level. The a- and b-adrenergic receptors respond to endogenous catecholamines or exogenous pharmacologic agents (e.g., drugs). Drugs that can selectively activate or block specific types of adrenergic receptors have been developed to treat high blood pressure.

Central Nervous System Responses

It is not surprising that the CNS, which plays an essential role in regulating vasomotor tone and blood pressure, would have a mechanism for controlling the blood flow to the cardiovascular centers that control circulatory function. When the blood flow to the brain has been sufficiently interrupted to cause ischemia of the vasomotor center, these vasomotor neurons become strongly excited, causing massive vasoconstriction as a means of raising the blood pressure to levels as high as the heart can pump against. This response is called the CNS ischemic response, and it can raise the blood pressure to levels as high as 270 mm Hg for as long as 10 minutes. The CNS ischemic response is a last-ditch stand to preserve the blood flow to vital brain centers; it does not become activated until blood pressure has fallen to at least 60 mm Hg, and it is most effective in the range of 15 to 20 mm Hg. If the cerebral circulation is not reestablished within 3 to 10 minutes, the neurons of the vasomotor center cease to function, so that the tonic impulses to the blood vessels stop and the blood pressure falls precipitously.

The Cushing reflex is a special type of CNS reflex resulting from an increase in intracranial pressure. When the intracranial pressure rises to levels that equal intra-arterial pressure, blood vessels to the vasomotor center become compressed, initiating the CNS ischemic response. The purpose of this reflex is to produce a rise in arterial pressure to levels above intracranial pressure so that the blood flow to the vasomotor center can be reestablished. Should the intracranial pressure rise to the point that the blood supply to the vasomotor center becomes inadequate, vasoconstrictor tone is lost, and the blood pressure begins to fall. The elevation in blood pressure associated with the Cushing reflex is usually of short duration and should be considered a protective homeostatic mechanism. The brain and other cerebral structures are located within the rigid confines of the skull, with no room for expansion, and any increase in intracranial pressure tends to compress the blood vessels that supply the brain.

Control of the Circulatory System

- Arterial blood pressure equals the product of cardiac output and total peripheral resistance.
- Arterial blood pressure is regulated in the short term by neural (autonomic nervous) and hormonal (renin-angiotensin-aldosterone-vasopressin) systems and in the long term by the ability of the kidney to regulate extracellular water and sodium balance.
- Local control of blood flow is regulated by local mechanisms that match blood flow to the metabolic needs of the tissue. Over the short term, the tissues autoregulate flow through the synthesis of vasodilators and vasoconstrictors derived from the tissue, smooth muscle, or endothelial cells, and over the long term by creation of a collateral circulation.
- Neural control of blood flow and cardiac function and, therefore, blood pressure occurs through the sympathetic and parasympathetic divisions of the autonomic nervous system. Sympathetic stimulation increases heart rate, cardiac contractility, and vessel tone (vascular resistance), whereas parasympathetic stimulation decreases heart rate.

AUTONOMIC RESPONSE TO CIRCULATORY STRESSES

The response of the cardiovascular system to the stresses of everyday living is mediated largely through the ANS. These stresses include postural stress, Valsalva's maneuver, and face immersion.

Postural Stress

During movement from the supine to the standing position, approximately 20% of the blood in the heart and lungs is displaced into the legs. The venous return to the heart is decreased, the stroke volume falls, and blood pressure decreases. As the blood pressure drops, the baroreceptors are stimulated and produce a reflex-mediated increase in heart rate and peripheral vascular resistance. These responses prevent the blood pressure from falling excessively when the standing position is assumed. With prolonged standing, an increase in plasma volume and the action of the skeletal muscle pumps aid in the return of blood to the heart. Decreased tolerance of the upright position causes orthostatic hypotension, which is discussed in Chapter 23.

Valsalva's Maneuver

Valsalva's maneuver, which involves forced expiration against a closed glottis, incites a sequence of rapid changes in preload and afterload stresses along with autonomically