

those already mentioned. The breathing of galloping animals is synchronized with the stride cycle in a 1:1 ratio (Fig. 12.11), whereas no strict synchronization occurs during trotting or walking. However, the locomotory muscles may affect ventilation even at these gaits, although the interaction is less obvious than in gallop.

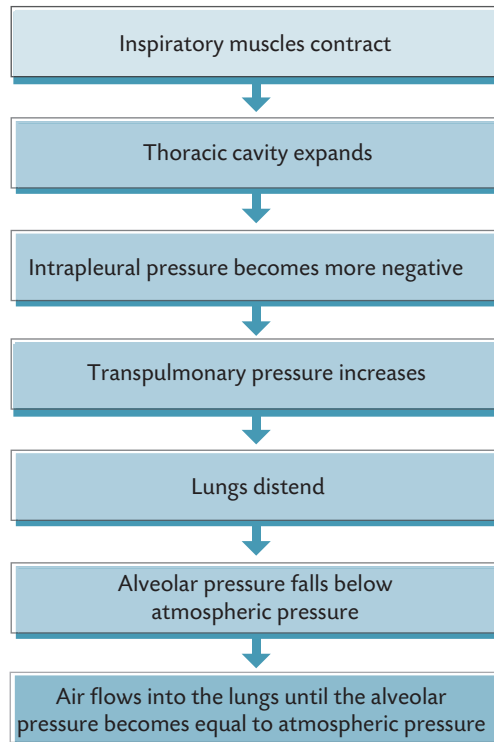
### Ventilation in diving mammals

In mammals specialized for diving (pinnipeds and cetaceans), breathing takes place at the water surface. During a dive, such animals display voluntary apnea (p. 441) ranging in duration from a few minutes to more than one hour in certain species. The walls of the conducting airways of diving mammals are strengthened, and, during deep dives, the gas in the lungs is compressed and shifted to these reinforced airways. As gas exchange does not occur between this part of the airways and pulmonary blood, there is no accumulation of excessive quantities of nitrogen in the blood. Thus, the animals are protected against bubble formation in the blood and tissues during rapid ascents from great depths. Mammals that are specialized for diving do not generally dive with fully inflated lungs, and their major oxygen reserves reside within the blood as oxyhemoglobin.

In contrast, due to the enhanced solubility of gases with increasing pressure, diving humans that are breathing compressed air accumulate increased amounts of dissolved nitrogen in blood and tissues. Some of the nitrogen that has dissolved at high pressure during the dive may be released as gas bubbles in blood and tissues if the ascent from depths greater than about 10 m occurs too rapidly. The most serious symptoms of this condition, which is called the “bends”, are due to local ischemia caused by clogged vessels.

### Pressures in the Airways and Thorax

Pressures in the airways and thorax are usually presented relative to atmospheric pressure, which, on average, is 760 mmHg (101.3 kPa) at sea level. A negative pressure value implies that the pressure is below atmospheric pressure, whereas a positive value indicates a pressure above atmospheric pressure. For example, a pressure of  $-5$  mmHg is 5 mmHg lower than atmospheric pressure.



**Figure 12.10** The sequence of inspiratory steps.

In order to simplify the discussion of ventilation, it is useful to define the following pressures (Fig. 12.12):

- alveolar pressure ( $P_{\text{alv}}$ )
- intrapleural pressure ( $P_{\text{pl}}$ )
- transpulmonary pressure ( $P_{\text{t}}$ )

*Alveolar pressure* is the pressure inside the alveoli.  $P_{\text{alv}}$  is about  $-1$  mmHg during inspiration, and increases to about 1 mmHg during expiration. Air does not flow through the airways in

Mammals specialized for diving deflate their lungs prior to deep dives

**Figure 12.11** Dorsoventral bends in the body of a galloping dog alternately compress and expand the lungs, thereby assisting both expiration and inspiration, which are strictly phase-locked to the stride cycle. Plus and minus symbols indicate positive and negative pressures exerted on the lungs by the locomotory movements. Modified from Kardong, 1995.

