breath

Metabolism is the sum of processes allowing a living cell to be alive. Defining the outer limit of every cell is a membrane, which forms a boundary between living and non-living space. Of course, with a multicellular organism, there are many cells, and the entire animal is considered to be alive. In response to the challenge of maintaining a livable environment for each cell, a circulatory system and a respiratory system are required to distribute nutrients and O_2 and to remove metabolic end-products, including CO_2.

In the honeybee, there is an additional level of emergent complexity**:** each bee is irrelevant as an individual**;** alone, she is unable to reproduce or to survive a single season or even to defend herself (use of her only weapon causes her own death). It's the colony in its hive that's the thing, the relevant individual, the *superorganism* **…** and the colony must also breathe.

THE RESPIRATORY SYSTEM. 113

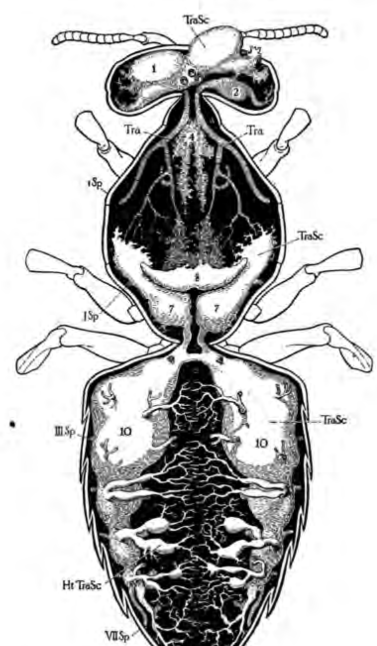

FIG. 50.—Tracheal system of worker as seen from above, one anterior pair of abdominal sacs (fig. 1, 9) removed and transverse ventral commissures of abdomen not shown.

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First let's take a look at the strange world of honeybee ventilation at the level of the single bee. Even close inspection of a forager returning to the hive from a 2 mile foray into the flower fields fails to reveal what one might look for**:** there's no mouth-panting to be seen. The mouth of a bee is used for collecting and sharing food and for construction of comb. All the breathing is happening through numerous tiny holes along the sides of the abdomen – too small to easily see. No lungs in a bee, either**:** small tubes - tracheae - connect to air sacs that send branches throughout the body and distribute gases directly. O_2 delivery and CO_2 pickup is not centralized, as it is in vertebrates, where gills or lungs are present; rather, an elaborate system of tiny air-filled tubes whoosh gases in and out throughout the body.

Consider this: the warm sea that bathes all the cells of a human body is the *interstitial fluid*, literally the “fluid between the spaces” around cells. In a sense, each cell is an island and, though interdependent, lives or dies within its own economy. The closed circulatory system of a human delivers O_2 and nutrient-rich blood via arteries and arterioles and then capillaries, where exchange with the interstitial fluid occurs. Venules and veins return blood depleted of O_2 and loaded with CO_2 to the central circulation and to the lungs for gas exchange.

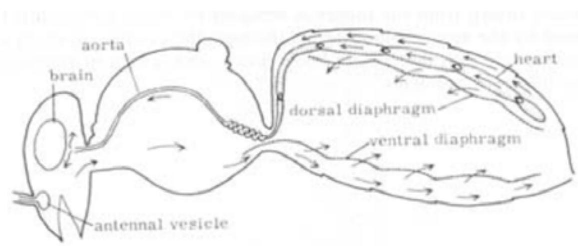

Fig. 20. Diagram illustrating the action of the heart and diaphragms.

In the honeybee, it’s the warm sea itself, the interstitial fluid (called *hemolymph*) that is circulated. The bee’s heart pumps _*hemolymph*_ into its aorta and into its head region. From there, the hemolymph flows freely around and among the channels between cells throughout the body of the bee, the general direction being backward toward the abdomen and the heart, where it re-enters through valves and is pumped again through heart and into aorta. The respiratory system is separately organized**:** gas exchange occurs directly between branching air tubes and the interstitial fluid.

Look at the image of brood comb. Think of the parallel layers of brood, packed in their comb, right in the center of the colony structure, surrounded and warmed by the cluster **…** must get pretty stuffy in there - lots of metabolism, with so many growing babies and adult bees in attendance. A coordinated air circulation system, constantly functioning and working without interruption is required for this nursery. The social organization of the honeybee colony provides this, with temperature and humidity and CO_2 being monitored (via various specific antennal receptors) to provide feedback and adjustment of airflow as needed.

A hive cavity generally has a *single, rather small opening to the outside world*, through which foragers move in and out in their daily work. This might be considered the *mouth* of the hive, and through this mouth, air exchange occurs by a rhythmic intake and exhaust - *tidal ventilation* - as the colony coordinates, with fanners placed strategically inside the hive and at the opening, allowing *the hive itself to inhale and exhale*, providing the gas exchange needed by the colony throughout the actively metabolizing combs of its dark interior. Here is a graph showing *breathing of a hive* – 3 breaths per minute as shown - air moving first out of the hive entrance and then reversing direction and flowing in.

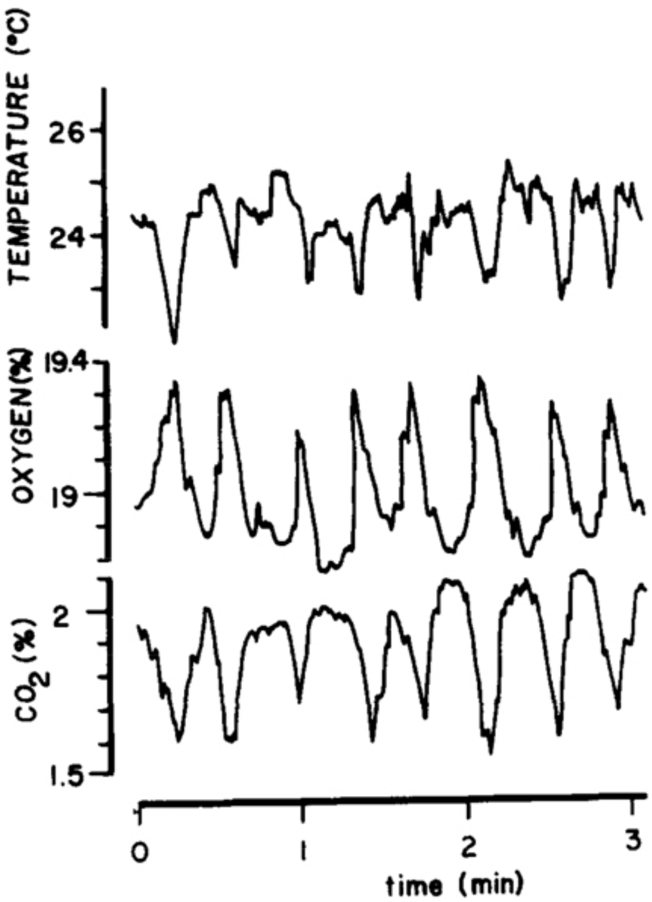

Fig. 2. Typical respiratory pattern during daytime of a group of 2000 honey bees. Temperatures and gas concentrations were continuously recorded at the entrance (A,B in Fig. 1) and indicated direction of air flow and breathing frequency, RF.

above graph from:
Journal of Insect Physiology: 1986
“Social Control of Air Ventilation in Colonies of Honey Bees”
– Southwick and Moritz

For more information and references regarding honeybee respiration and tidal ventilation of the honeybee hive, go to **imagessays.com** -> **breath**.