SMELL

ALTHOUGH VISION HAS BECOME THE DOMINANT SENSE IN HUMANS, THE SENSE OF SMELL (OLFACTION) REMAINS IMPORTANT TO SURVIVAL BECAUSE IT CAN WARN US OF HAZARDOUS SUBSTANCES IN OUR ENVIRONMENT. THE SENSES OF SMELL AND TASTE ARE CLOSELY LINKED.

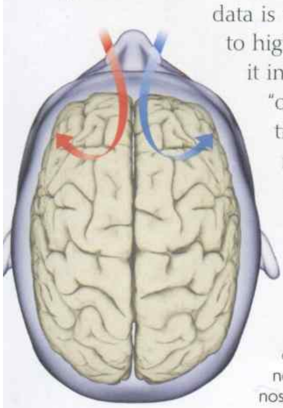
DETECTING SMELL

Like the sense of taste, smell is a chemical sense. Specialized receptors in the nasal cavity detect incoming molecules, which enter the nose on air currents and bind to receptor cells. Sniffing sucks up more odor molecules into the nose, allowing you to "sample" a smell. It is a reflex action that occurs when a smell attracts your attention, and can help warn of danger, such as smoke from a fire or rotting food. Olfactory receptors located high up in the nasal cavity send electrical impulses to the olfactory bulb, in the limbic area of the brain, for processing.

SMELL CENTERS IN THE BRAIN
The olfactory bulb is the smell gateway to the brain. Here, data about smells is processed in the forebrain (yellow), then sent to various areas of the brain, including the olfactory cortex adjacent to the hippocampus (red).

SMELL PATHWAYS

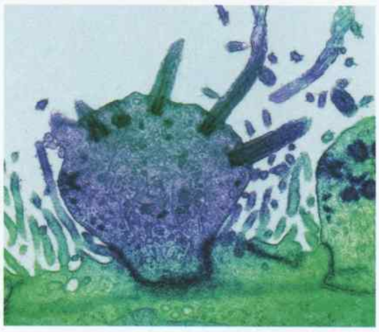
Odors are initially registered by receptor cells in the nasal cavity. These send electrical impulses along dedicated pathways to the olfactory bulb (each nostril connects to one olfactory bulb). The olfactory bulb is part of the brain's limbic system, the seat of our emotions, desires, and instincts, which is why smells can trigger strong emotional reactions. Once processed by the olfactory bulb, data is transmitted via three olfactory pathways to higher centers in the brain that process it in different ways. This process is called "orthonasal" smelling, in which smell data travels along pathways directly from the nose (see opposite). In "retronasal" smelling (see p.99), odors also have a flavor component that enters the olfactory pathways via the mouth.



SAME-SIDE PROCESSING
Unlike data gathered by the other sense organs, odors are processed on the same, not opposite, side of the brain as the nostril the sensory data was sent from.

RECEPTOR ARRAYS

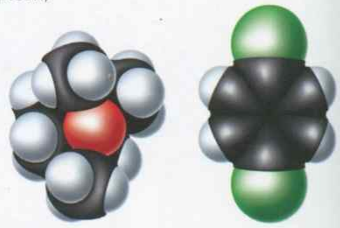
There are around 1,000 types of receptor cell in the nasal cavity, but we can distinguish around 20,000 different smells so, clearly, there is more to smell reception than "one receptor, one smell." Research shows that each receptor has zones on it, each of which responds to a number of smell molecules. Also, multiple receptors respond to the same smell molecule–it may be that each receptor binds to a different part of it. A specific smell will activate a specific pattern or "array" across the receptors, so that each smell has its own "signature." When the receptors forming a specific pattern are activated, this signature is sent to the brain for processing.



OLFACTORY RECEPTOR CELL
This colored electron micrograph shows tiny cilia projecting from a receptor cell. Odor molecules bind to the cilia and activate the receptor.

THE CHEMISTRY OF SMELL

There is still much to be learned about the relationship between chemical structure and smell. Scientists have identified eight primary odors (rather like the three primary colors): camphorous, fishy, malty, minty, musky, spermatic, sweaty, and urinous. Smells are often produced by a combination of many different smell molecules, often from different categories. Comparisons of the structures of smell molecules within each category have shown some similarities–for example, minty smelling compounds often share a similar molecular structure. However, tiny differences in molecular structure can produce very different smells. Octanol, a fatty alcohol, smells like oranges, while octanoic acid, a saturated fatty acid that differs from octanol by only one oxygen atom, smells like sweat.



SMELL AND MOLECULAR STRUCTURE
These two molecules differ significantly in their chemical structure, yet both of them conjure the same characteristic "mothball" smell of camphor. They probably share a common structural feature that has the same odorant (smell) property when picked up by olfactory receptor cells.

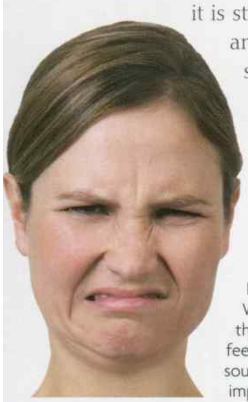
PRIMARY SMELLS
Scientists investigating the perception of smell have attempted to identify primary odors, which can be combined with one another to produce the much larger range of smells that we experience. To date, eight primary odors have been identified, including the distinctive smell of fish.

PERCEIVING SMELL

SMELL IS MORE LIKELY TO EVOKE EMOTION AND MEMORY THAN THE OTHER SENSES. THE FACT THAT OLFACTORY AREAS OF THE BRAIN EVOLVED EARLY ON AND ARE WIRED INTO THE PRIMITIVE BRAIN SUGGESTS THAT SMELL IS VITAL FOR OUR SURVIVAL, AS WELL AS THE SURVIVAL OF OTHER ANIMALS.

THE EVOLUTION OF SMELL

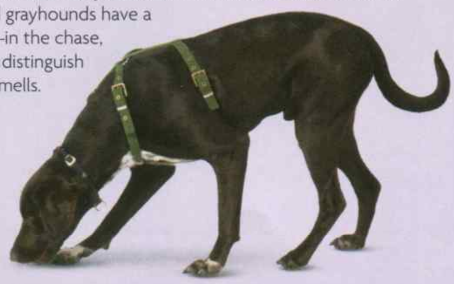
The smell brain, centered around the olfactory bulb in the limbic system, is of ancient origin, having evolved about 50 million years ago in fish. The sense of smell was overtaken in importance by the sense of vision when humans began to walk on two legs, although it is still dominant for many animals. But smell is an important aspect of survival for humans, shown in the fact that we take prompt action if we smell gas or smoke, for example. It also plays an important role in sexual selection, emotional responses, and forming preferences for food and drink. All of these factors were probably of key importance in the lives of our ancestors.



DISGUST
When a bad odor is detected, such as that of rotting meat, it is natural to both feel and express disgust. Avoidance of the source of the odor follows, and it is almost impossible to eat food that smells bad.

OLFACTION IN ANIMALS

Although humans can smell some odors at a concentration as low as one part per trillion, our sense of smell is weak compared to that of other animals. The size of the surface area of the olfactory epithelium (see p.95) and the density of smell receptor cells indicate how sensitive an animal's sense of smell is. Dogs, for example, can identify a particular human from just a few odor molecules. Northern dogs, such as huskies and jackals, are renowned for their sense of smell. Hunting dogs and grayhounds have a weaker sense of smell—in the chase, they don't have time to distinguish prey from background smells.



SNIFFER DOG
A breed combining the behavioral characteristics of a domestic dog and a jackal's sense of smell makes an ideal sniffer dog for security work.

SMELL ACROSS SPECIES

SPECIES	NUMBER OF OLFACTORY RECEPTOR CELLS	AREA OF OLFACTORY EPITHELIUM
Human	12 million	1½ square in (10 square cm)
Cat	70 million	2¼ square in (21 square cm)
Rabbit	100 million	Data not available
Dog	1 billion	26½ square in (170 square cm)
Bloodhound	4 billion	59 square in (381 square cm)

SMELL PREFERENCES

Whether we find a smell nice, nasty, or neutral is very subjective and depends upon familiarity, intensity, and perception as pleasant or unpleasant. It is not clear if preferences are innate or learned, but much experimental evidence supports the latter possibility. Associative learning links pleasant smells to pleasant experiences, and vice versa. For example, people who fear the dentist do not like the clovelike smell of eugenol, which is used in dental cement; those without a fear of the dentist react positively or neutrally to this odor.

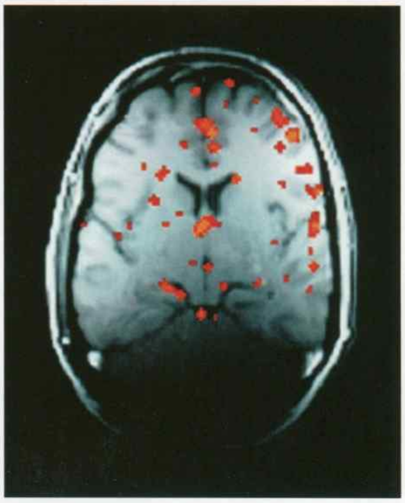
SUBJECTIVE RESPONSES
The distinctive smell of the durian fruit is perceived by some as revolting but others find it extremely tempting.

THE SIX WORST SMELLS IN THE WORLD

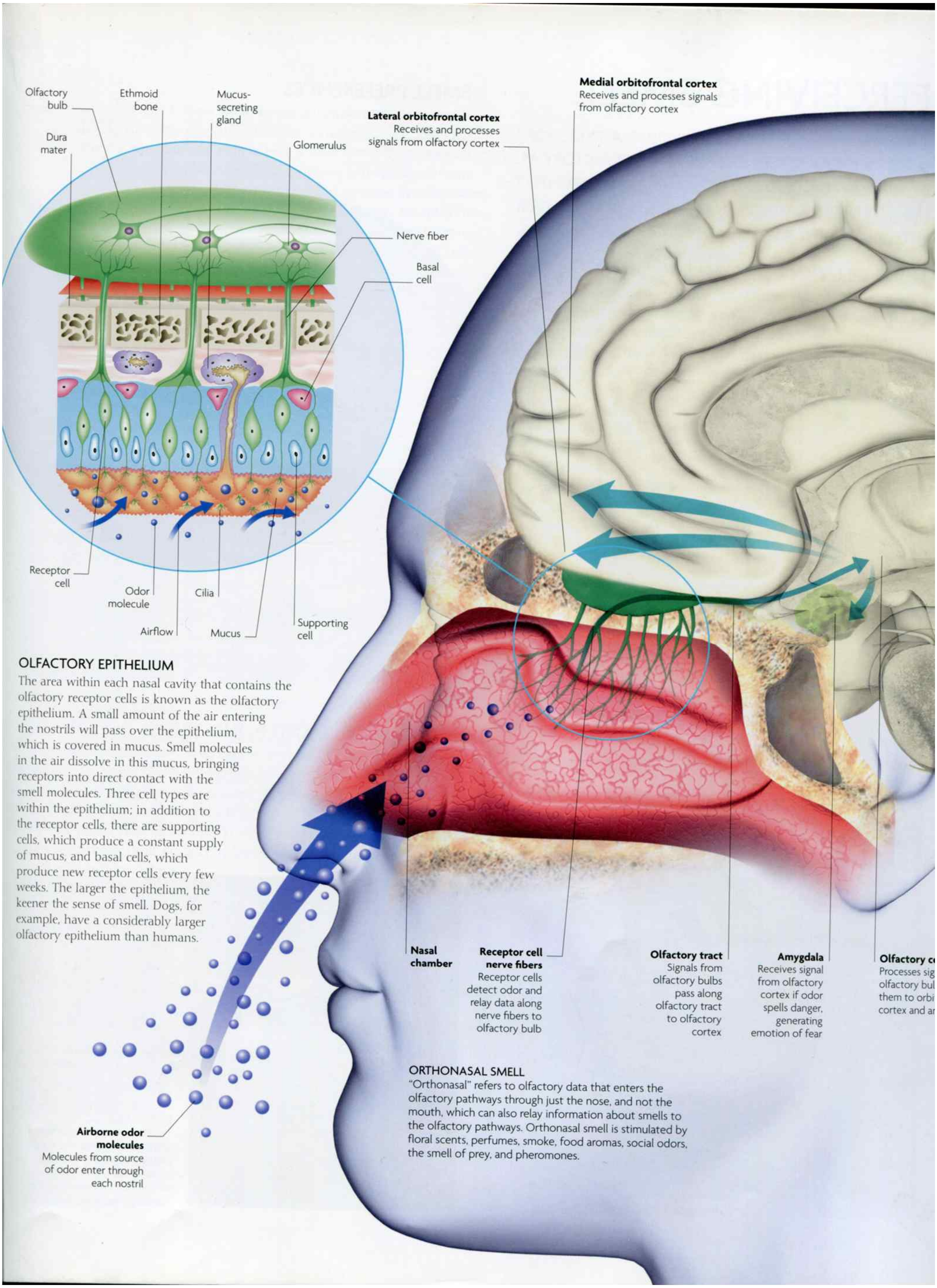
SMELL	DESCRIPTION
Decaying flesh	Repulsive to most people; may evoke thoughts of death
Skunk odor	Horrible to most, but a few people find it "interesting"
Vomit	Often associated with illness, which may heighten disgust
Feces or urine	Caused by gas released as bacteria break down food residue
Decaying food	Triggers an "adaptive" response to food that could cause illness
Isonitriles	Chemicals in nonlethal weapons described as "world's worst smell"

STEREOSCOPIC AND BLIND SMELL

It is generally believed that the human sense of smell has atrophied in relation to our other senses, but recent research shows that humans can still effectively track a scent. Using both nostrils to sample a smell, the human brain uses both sets of data to accurately pinpoint the location of the source of the odor. Therefore, as with vision and hearing, smell can be "stereoscopic," relying on both nostrils for a full understanding of a scent. "Blind" smell refers to the ability of the brain to detect a smell without being consciously aware of it, which has been demonstrated in experiments using fMRI scans showing how olfactory areas are activated without the participant's knowledge.



BLIND SMELL ACTIVATION
This fMRI scan shows widespread activity throughout the brain in areas including the thalamus (just above center), on exposure to an odor at concentrations that cannot be detected consciously.



OLFACTORY EPITHELIUM

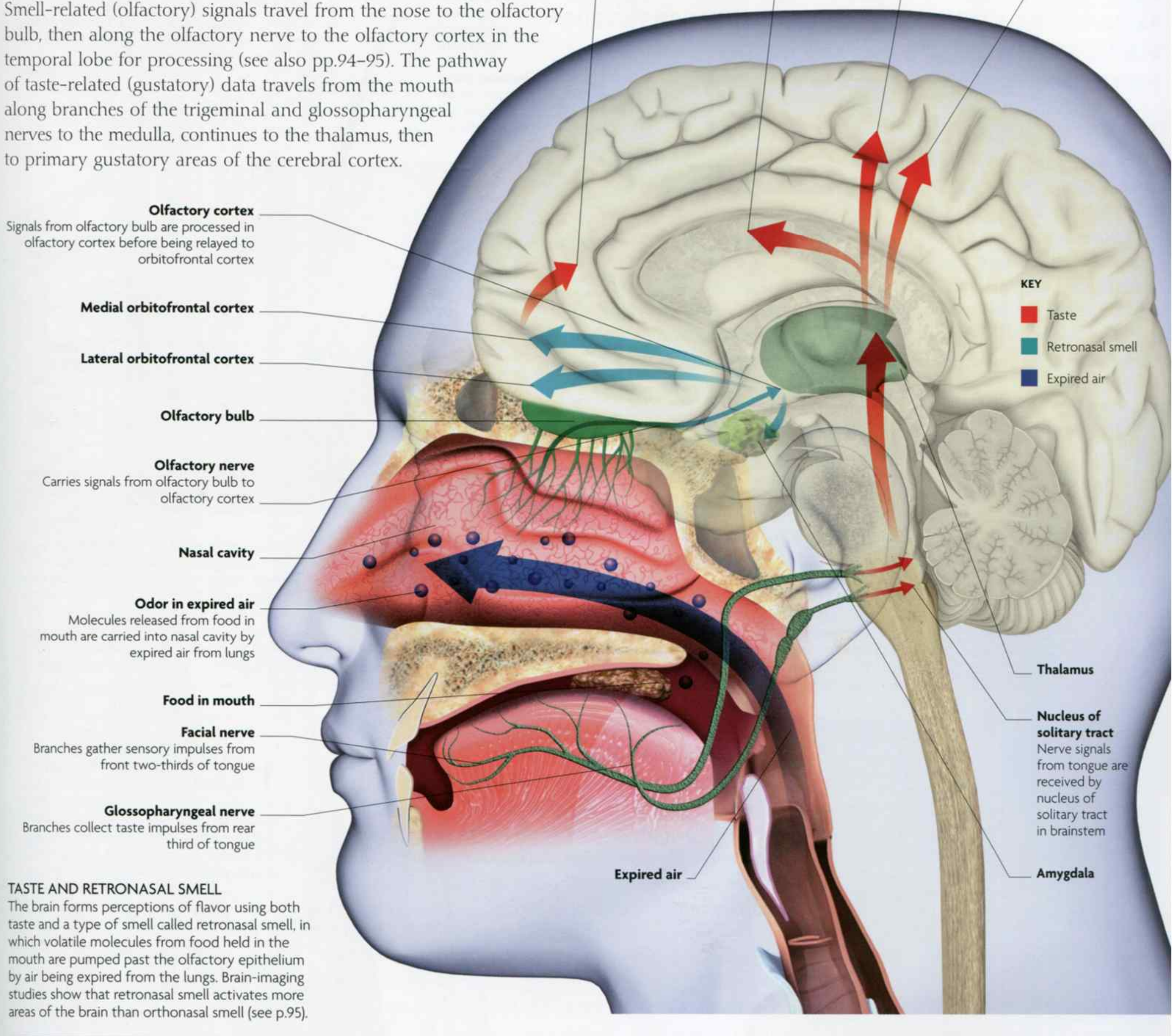
The area within each nasal cavity that contains the olfactory receptor cells is known as the olfactory epithelium. A small amount of the air entering the nostrils will pass over the epithelium, which is covered in mucus. Smell molecules in the air dissolve in this mucus, bringing receptors into direct contact with the smell molecules. Three cell types are within the epithelium; in addition to the receptor cells, there are supporting cells, which produce a constant supply of mucus, and basal cells, which produce new receptor cells every few weeks. The larger the epithelium, the keener the sense of smell. Dogs, for example, have a considerably larger olfactory epithelium than humans.

ORTHONASAL SMELL

"Orthonasal" refers to olfactory data that enters the olfactory pathways through just the nose, and not the mouth, which can also relay information about smells to the olfactory pathways. Orthonasal smell is stimulated by floral scents, perfumes, smoke, food aromas, social odors, the smell of prey, and pheromones.

TASTE AND SMELL BRAIN AREAS

Taste and smell are both chemical senses–receptors in the nose and mouth bind to incoming molecules, generating electrical signals to send to the brain. Both sets of signals pass along the cranial nerves. Smell-related (olfactory) signals travel from the nose to the olfactory bulb, then along the olfactory nerve to the olfactory cortex in the temporal lobe for processing (see also pp.94–95). The pathway of taste-related (gustatory) data travels from the mouth along branches of the trigeminal and glossopharyngeal nerves to the medulla, continues to the thalamus, then to primary gustatory areas of the cerebral cortex.



TASTE AND RETRONASAL SMELL
The brain forms perceptions of flavor using both taste and a type of smell called retronasal smell, in which volatile molecules from food held in the mouth are pumped past the olfactory epithelium by air being expired from the lungs. Brain-imaging studies show that retronasal smell activates more areas of the brain than orthonasal smell (see p.95).