



# Particle deposition and sensory drive

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Email: sapoinde@buffalo.edu**Abstract**

The mutualism between chemical cues emitted into the air and variations in how primates respond to them using olfaction has demonstrated aspects of species-specific adaptations. Building on this mutualism we can look at particle deposition as another means to understanding how various environments may have elicited biological changes that enable efficient communication. Research on particle movement and deposition within the nasal cavity is largely based on questions about health as it relates to drug delivery systems and overall olfactory function in modern humans. With increased access to 3D models and the use of computational fluid dynamic analysis, researchers have been able to simulate site-specific deposition, to determine what particles are making it through the nasal cavity to the main olfactory epithelium, which ultimately leads to processing in the olfactory bulb. Here we discuss particle deposition research, sensory drive and their potential applications to evolutionary anthropology.

**KEYWORDS**

morphology, nasal cavity, olfactory cues, perceptual tuning

## 1 | INTRODUCTION

Evolutionary anthropologists have a long-standing interest in nasal morphology, looking to define and contextualize the morphological variation seen across modern humans and throughout the hominin fossil record (Box ).<sup>10,11</sup> At present the prevailing hypothesis used to explain the evolution of the human nose, which Jacobs<sup>12</sup> refers to as the “conditioning hypothesis,” suggests that the external nose evolved to support the need to warm and humidify air prior to reaching the lungs. Additionally, the nasal cavity plays an essential role in this process as the site where the exchange between heat and moisture takes place.<sup>13</sup> The majority of research supporting the link between nasal morphology and climate focuses on the nasal vestibules, or the triangular-shaped entry points of the nose and the shape of the septum and cartilage that form the distinctive pyramid shape seen in our noses. However, Noback et al.<sup>14</sup> found a similar relationship looking at the bony structure of the nasal cavity and the nasopharynx, where the bony cavity variation was associated with temperature and the nasopharynx variation was associated with humidity, other studies have also noted a relationship between latitude and nasal morphology.<sup>13</sup> Despite the focus on the nasal cavity as a tool for conditioning air, its function and/or selection for olfaction has become an increasingly prominent

point of discussion.<sup>12,15</sup> This line of research and discourse has the potential to redefine the selection pressures we currently associate with nasal morphology as a standalone explanation. It is possible that there is a level of mutuality, where nasal morphology maximizes the ability to humidify air for the purpose of breathing as well as olfaction given that humidity is associated with volatile emissions.<sup>16</sup> It is likely that there is a collection of selective pressures that produced the morphological variation we see today. In an effort to have a more comprehensive understanding of these evolutionary pressures, defining the extent to which the sense of smell is facilitated across the Primates order can inform our understanding of primate olfaction as it functions today and how it evolved over the last 60 million years.<sup>17</sup>

To determine the relationship between nasal morphology and the role it plays in variations in olfactory ability, we can build on research describing the mutualism seen between the volatile organic compounds (VOCs) emitted into the air and variations in how non-human primates (hereafter primates) respond to such cues.<sup>18</sup> The results of this research have illuminated aspects of species-specific olfactory adaptations. Additionally, we can simulate the transportation of VOCs through the nasal cavity based on airflow dynamics as well as how those VOCs are deposited onto the mucosal lining of the nasal cavity, known as particle deposition. To accurately simulate particle

**BOX 1 Glossary**

**Nasopharynx:** The nasopharynx connects the nasal cavity and oropharynx.<sup>1</sup>

**Olfactory epithelium:** Olfactory epithelium is a mucosal layer of tissue, with supporting cells and sensory neurons that line the ethmoturbinals of the internal nasal fossa.<sup>2</sup>

**Olfactory receptor neurons:** Within the olfactory epithelium these neurons project into the nasal fossa and facilitate transduction of odorant information.<sup>3</sup>

**Olfactory bulb:** This region of the brain is the first processing station in the central olfactory pathway.<sup>4</sup>

**Environmental odorants:** Airborne chemical compounds within the environment.<sup>5</sup>

**Computational fluid dynamics:** an integrated approach to studying fluids in motion, bringing together fluid mechanics, mathematics, and computer science.<sup>6</sup>

**Nasal valve region:** The anterior portion of the nasal cavity, from the nostril to the nasal valve (NV), is the place of highest nasal resistance to airflow.<sup>7</sup>

**Olfactory recess:** a space at the back of the nasal airway that facilitates prolonged air circulation that is not present in haplorrhine primates but is present in most non-primate mammals and strepsirrhines.<sup>8</sup>

**Macrosmatic:** species with a greater level of olfactory function.<sup>9</sup>

deposition and general VOC movement within the nasal cavity, it is important to know what sized VOCs are present within the environment, and therefore what sized particles we should use while reconstructing particle airflow and deposition.

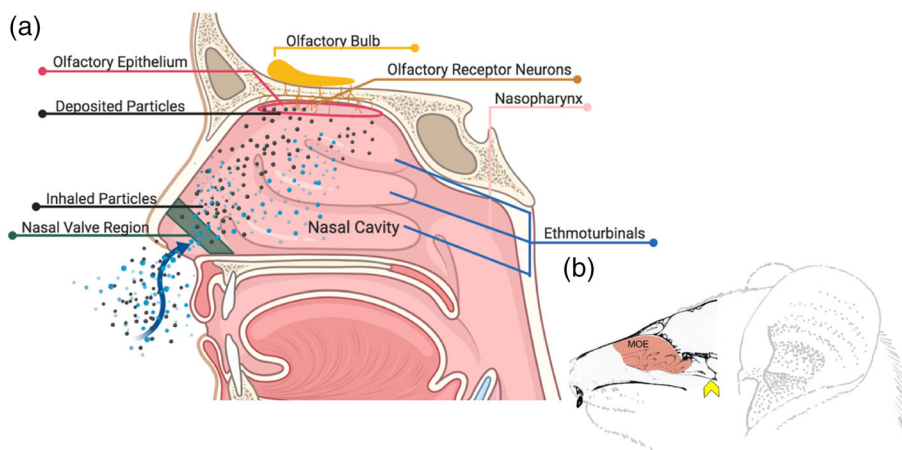
Broadly speaking, the sense of smell is the result of inhaled particles that dissolve into the mucus lining covering the olfactory epithelium.<sup>19</sup> After deposition and absorption, the peripheral olfactory sensory neurons recognize these chemical compounds in the olfactory epithelium, where olfactory receptors facilitate signal transduction in the olfactory bulb<sup>20</sup> (Figure 1). This multi-step process, from an evolutionary perspective, creates the opportunity for variation and optimization across various species in different environments and during different seasons.

From a morphological perspective, variability in the nasal cavity can promote either increased or decreased particle deposition efficiency relative to particle size. To address this relationship and the question of how variable nasal morphology may influence deposition there needs to be an effort to characterize the chemical environment. Identifying the VOC's present in an environment is already a common practice,<sup>6</sup> but also we need to determine the size of those VOC's

which are the most prominent signals and characterize the variation in nasal morphology of key species across different environments. Ultimately, evolutionary anthropologists can benefit from research simulating particle movement and deposition as the dynamic relationship between particle deposition and olfaction can act as another mechanism by which we can identify adaptations.

## 2 | THE CHEMICAL WORLD

The chemical environments that humans and primates inhabit are comprised of a wide array of chemical compounds that vary in size.<sup>21</sup> Researchers studying how the chemical environment informs primates have provided increasing evidence that the chemical compounds emitted by fruits and other vegetation are important cues that primates can understand and use to make decisions.<sup>22–25</sup> For example, fruits that are more regularly eaten by lemurs, a prominent seed disperser in Madagascar, emit a substantially larger amount of VOCs when ripe compared to fruits that are not regularly eaten by lemurs.



**FIGURE 1** (a) Sideview of the human nasal anatomy, including a representation of environmental particles inhaled into to nasal cavity where some are deposited into the mucus lining, especially the olfactory epithelium, which is one of the necessary steps in our sense of smell. Here we include key anatomical features discussed within the text. (b) Red overlay represents the approximate region where the main olfactory epithelium (MOE) covers nasal turbinates 1–4 in *Microcebus* sp. yellow arrowhead pointing to the olfactory recess. Figure modified from Garrett and Steiper, 2014 [Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

There is not a comparable increase in VOCs in fruits eaten by animals that are less reliant on olfaction,<sup>24</sup> suggesting that these fruits are signaling the lemurs. Animal scat from species with varying diet types also show distinct chemical profiles, this is a byproduct of the varying chemical composition of the foods they are eating.<sup>26</sup> This distinct profile can also act as an olfactory cue for others animals within the environment who are likely able to use these distinct profiles to find or avoid certain animals. In addition to the presence of a variety of chemical compounds, perception of those cues adds another layer to how information is communicated. In humans, larger more complex compounds are more “appealing” compared to smaller less complex compounds,<sup>27</sup> further highlighting the nuanced relationship between chemical compounds and the intended receiver.

Chemical cues are functional across a relatively longer distance compared to the reach of our sense of touch and vision.<sup>28</sup> This range is an intermediate position among other senses, where auditory cues are the most far-reaching. Chemical cues can indicate the presence of resources, conspecifics, and predators. Chemotaxis, the movement toward (or away from) a source of chemical cues is an essential component of the successful behavioral ecology of most animals.<sup>29</sup> These signals also outlast many other sensory cues in terms of latency.<sup>28</sup>

Through an ongoing discourse among anthropologists, psychologists, and biologists, it is accepted that humans and other primates have a better sense of smell than previously understood.<sup>30–31</sup> As we do away with the concept that humans and our closest cousins have traded olfaction for vision, we should consider that olfaction may have played a more substantial role in shaping our evolution.

### 3 | SENSORY DRIVE

Variation in the environment can drive divergence by means of perceptual tuning.<sup>32</sup> Environmental cues may favor individuals with a sensitivity to different chemical compounds, and natural selection will have acted on these sensitivities to facilitate signal matching, but this is dictated by the local chemical environment.<sup>33</sup> When the chemical environments differ, the selection pressure for a particular signal will also differ, which over time could lead to divergence in morphological traits, such as nasal cavity shape ultimately affecting species-level olfactory ability.

The sensory drive hypothesis<sup>34</sup> suggests that evolution influences signal production and signal detection in a dynamic world, predicting that selection favors mechanisms that facilitate communication depending on the environment.<sup>34</sup> Through this hypothesis, Endler<sup>35</sup> describes how the transmission of signals, habitat-specific perceptual tuning and signal matching can influence the evolution of the signal characteristics themselves. Chemical cues and the intended recipient must work together to prompt the desired response, so in order to consider a signal to be adaptive the receiver must select for the cue of the emitter to facilitate communication. The influence of sensory drive on olfaction is essential to understanding how chemical communication evolved and how it may be affected by changing environmental conditions. Despite its importance as a sensory modality, olfaction receives little attention in the sensory drive literature.<sup>36</sup> As a result,

there are few clear examples of sensory drive in olfaction. Researchers have reviewed this topic noting how the environment will definitely influence signal transmission,<sup>37</sup> there are a few aquatic studies in artificial streams, but there is a consistent call for more work focused on the relationship between olfactory signals and sensory drive. Studying the relationship between the size of VOC's released into the environment, what we already know about olfactory cues informing primate decisions, and nasal cavity variation is a great opportunity to test aspects of the sensory drive hypothesis.

### 4 | PARTICLE DEPOSITION

Considering what we know about particle deposition in humans and other animal models, there is the potential to uncover further one of the mechanisms that may contribute to the variation in olfactory ability seen across primate species. Though historically this research has focused on applications to medicine, health, and in testing the conditioning hypothesis, we see the potential for this research to help evolutionary anthropologists and biologists better understand morphological variation, evolutionary selection pressures, sensory drive, and olfactory decision-making.

There is a collection of experimental studies measuring particle deposition in the human nasal passage, using in vivo methods,<sup>38,39</sup> nasal casts,<sup>40</sup> and 3D reconstructions.<sup>41</sup> The bulk of this research sought to improve nasal delivery systems for medications<sup>42</sup> and understand our susceptibility to pollutants (e.g., metal nanoparticles reaching the brain through the nasal epithelium by way of the olfactory bulb),<sup>43</sup> this continues to be the primary focus of work in nasal particle deposition today.<sup>44,45</sup> As a result of these studies, researchers have determined that deposition efficiency is mainly a function of particle size and density, airflow rate, and nasal cavity geometry.

Inhaled air is filled with particles, but not all of these particles will be deposited on the main olfactory epithelium, and furthermore, even fewer will reach the superiorly oriented olfactory epithelium where particles are absorbed and eventually interpreted by the olfactory bulb and downstream regions in the brain. Computational fluid dynamics (CFD) and 3D nasal cavity reconstructions allow researchers to look at site-specific particle deposition, improving our ability to understand the relationship between particle deposition and the diverse measures that broadly define olfactory ability, such as odor sensitivity and discrimination.<sup>46</sup> Kublik and Vidgren<sup>47</sup> reinforced the findings that particle size is one of the most crucial factors that determine where particles are deposited, typically defined through a measure known as particle deposition efficiency. The relationship between particle size and nasal deposition efficiency at a set airflow rate tends to follow a pattern where particles between 0.5 and 1.0  $\mu\text{m}$  have a lower deposition efficiency and particles below and above this range show higher deposition efficiency.<sup>48</sup>

In even smaller particles, those ranging in size between 1.0 and 2.0 nm had the highest deposition efficiency.<sup>49</sup> Also, Garcia and colleagues<sup>49</sup> noted that compared to rats, humans have lower olfactory deposition efficiency, which was explained by the fact that rats have a

higher proportion of olfactory epithelium within their nasal cavity and a narrower nasal passageway.<sup>49</sup> The anatomical variations in the olfactory region and the nasal valve region strongly affect airflow patterns and odorant transport, which ultimately can affect olfactory ability.<sup>50</sup> Considering site-specific particle deposition simulation and how it relates to olfactory capacity, it is important to note a large proportion of the olfactory epithelium lines the olfactory recess.<sup>51</sup> In the olfactory recess, which is present in many non-primate mammals and strepsirrhines, inhaled air can be sequestered, allowing inhaled particles to recirculate improving their likelihood of deposition and absorption.<sup>51</sup> In addition, the olfactory recess also slows air movement, allowing particles more time for deposition.<sup>52,53</sup> Because of this, chemical compounds inhaled by primates with an olfactory recess have more time to deposit on the mucosal layer and bind to receptors.

In 2019, Simth<sup>54</sup> was among the first to apply CFD and particle deposition analysis to a primate nasal cavity. This study highlighted the complicated nature of defining species using binary terms. The pygmy slow loris as a strepsirrhine possess traits congruent with macrosmatic anatomy, yet their airflow patterns do not segregate between olfaction and respiration in a way that you would expect from a species specialized for olfaction, such as dogs, who do partition nasal airflow for breathing and olfaction.<sup>55</sup> This look into how CFD and particle deposition research is already informing questions about primate evolution only emphasizes the possible applications of this well-established field on evolutionary anthropology.

## 5 | CONCLUSION

Physicists and chemists use a host of high-precision instruments that can measure particle size. We think these tools should also be employed by anthropologists. By looking at the information we can gain from particle deposition research through an evolutionary lens, we can begin to address some of the questions about our evolution that have previously evaded us. Variation in nasal morphology has been clearly documented in the hominin fossil record, in modern humans, and in other primates. Currently, we accept that climate (e.g., temperature and humidity), and the need to condition inhaled air before it reaches our lungs is a driver for nasal cavity variation, but emerging theories about olfaction as a driver highlight the need to have a closer look at species-specific mechanisms for communication and other interactions with their environment. How are the VOCs emitted by the environment used to convey information to primates? Do these VOCs vary in size/dimension? And is there a relationship between the VOCs emitted, their size, and the nasal cavity morphology of the primates responding to them? Ultimately, we are asking how we can use techniques from particle deposition and 3D computational fluid dynamics research to shed light on ongoing questions in evolutionary anthropology. How particles are deposited within the nasal cavity and the role our sense of smell may have played in driving variation warrants the attention of anyone interested in how humans evolved.

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## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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## REFERENCES

- [1] Lok BH, Setton J, Ho F, Riaz N, Rao SS, Lee NY. 2013. Nasopharynx. In: Halperin EC, Wazer DE, Perez CA, Brady LW, editors. *Perez and Brady's principles and practice of radiation oncology*, 6th ed. Philadelphia: Wolters Kluwer/Lippincott Williams and Wilkins. p 730–760.
- [2] Gottfried JA. 2006. Smell: central nervous processing. In: Hummel T, editor. *Taste and smell*, Basel: Karger Publishers. p 44–69.
- [3] Ashwell K. 2012. The olfactory system. In: Watson C, Paxinos G, Puelles L, editors. *The mouse nervous system*, San Diego: Academic Press. p 653–660.
- [4] Masurkar AV, Chen WR. 2009. Olfactory bulb physiology. In: Masurkar AV, Chen WR, editors. *Olfactory bulb physiology*, New York: Elsevier. p 77–86.
- [5] Nevo O, Heymann EW. 2015. Led by the nose: Olfaction in primate feeding ecology. *Evol Anthropol* 24:137–148.
- [6] Tu J, Yeoh GH, Liu C. 2018. *Computational fluid dynamics: a practical approach*. Oxford: Butterworth-Heinemann. p 1.
- [7] Nigro CEN, de Aguiar Nigro JF, Mion O, Mello JF Jr. 2009. Nasal valve: Anatomy and physiology. *Braz J Otorhinol* 75:305–310.
- [8] Smith TD, Rossie JB, Bhatnagar KP. 2007. Evolution of the nose and nasal skeleton in primates. *Evol Anthropol* 16:132–146.
- [9] Smith TD, Bhatnagar KP. 2004. Microsmatic primates: Reconsidering how and when size matters. *Anat Rec B New Anat* 279:24–31.
- [10] Churchill SE, Shackelford LL, Georgi JN, Black MT. 2004. Morphological variation and airflow dynamics in the human nose. *Am J Hum Biol* 16:625–638.
- [11] de Azevedo S, González MF, Cintas C, et al. 2017. Nasal airflow simulations suggest convergent adaptation in Neanderthals and modern humans. *Proc Natl Acad Sci U S A* 114:12442–12447.
- [12] Jacobs LF. 2019. The navigational nose: A new hypothesis for the function of the human external pyramid. *J Exp Biol* 222:186924.
- [13] Franciscus RG, Long JC. 1991. Variation in human nasal height and breadth. *Am J Phys* 85:419–427.
- [14] Noback ML, Harvati K, Spoor F. 2011. Climate-related variation of the human nasal cavity. *Am J Phys* 145:599–614.
- [15] Jacobs LF. 2012. From chemotaxis to the cognitive map: The function of olfaction. *Proc Natl Acad Sci U S A* 109:10693–10700.
- [16] Vallat A, Gu H, Dorn S. 2005. How rainfall, relative humidity and temperature influence volatile emissions from apple trees in situ. *Phytochemistry* 66:1540–1550.
- [17] Kawamura S, Melin AD. 2017. Evolution of genes for color vision and the chemical senses in primates. In: Saitou N, editor. *Evolution of the human genome I*, Tokyo: Springer. p 181–216.
- [18] Valenta K, Chapman CA. 2018. Primate-plant mutualisms: is there evidence for primate fruit syndromes? In: Kalbitzer U, Jack KM, editors. *Primate life histories, sex roles, and adaptability*, Cham, Switzerland: Springer. p 245–255.

- [19] Zhao K, Dalton P. 2007. The way the wind blows: Implications of modelling nasal airflow. *Curr Allergy Asthma Rep* 7:117–125.
- [20] Touhara K, Vosshall LB. 2009. Sensing odorants and pheromones with chemosensory receptors. *Annu Rev Physiol* 71:307–332.
- [21] Hudson R. 1999. From molecule to mind: The role of experience in shaping olfactory function. *J Comp Physiol A* 185:297–304.
- [22] Valenta K, Burke RJ, Styler SA, Jackson DA, Melin AD, Lehman SM. 2013. Colour and odour drive fruit selection and seed dispersal by mouse lemurs. *Sci Rep* 3:2424.
- [23] Nevo O, Valenta K. 2018. The ecology and evolution of fruit odor: Implications for primate seed dispersal. *Int J Primatol* 38:338–355.
- [24] Nevo O, Razafimandimby D, Jeffrey JAJ, Schulz S, Ayasse M. 2018. Fruit scent as an evolved signal to primate seed dispersal. *Sci Adv* 4:eat4871.
- [25] Melin AD, Nevo O, Shirasu M, et al. 2019. Fruit scent and observer colour vision shape food-selection strategies in wild capuchin monkeys. *Nat Commun* 10:2407.
- [26] Dominy NJ, Lucas PW, Osorio D, Yamashita N. 2001. The sensory ecology of primate food perception. *Evol Anthropol* 10:171–186.
- [27] Saraiva MJ, Salvador ÂC, Fernandes T, et al. 2014. Three mammal species distinction through the analysis of scats chemical composition provided by comprehensive two-dimensional gas chromatography. *Biochem Syst Ecol* 55:46–52.
- [28] Keller A, Vosshall LB. 2016. Olfactory perception of chemically diverse molecules. *BMC Neurosci* 17:55.
- [29] Gaudry Q, Nagel KI, Wilson RI. 2012. Smelling on the fly: Sensory cues and strategies for olfactory navigation in drosophila. *Curr Opin Neurobiol* 22:216–222.
- [30] Shepherd GM. 2004. The human sense of smell: Are we better than we think? *PLoS Biol* 2:146.
- [31] McGann JP. 2017. Poor human olfaction is a 19th-century myth. *Science* 356:eaam7263.
- [32] Boughman JW. 2002. How sensory drive can promote speciation. *Trends Ecol Evol* 17:571–577.
- [33] Levine JS, MacNichol EF Jr. 1979. Visual pigments in teleost fishes: Effects of habitat, microhabitat, and behavior on visual system evolution. *Sens Process* 3:95–131.
- [34] Endler JA. 1992. Signals, signal conditions, and the direction of evolution. *Am Nat* 139:S125–S153.
- [35] Endler JA. 1993. Some general comments on the evolution and design of animal communication systems. *Philos Trans Royal Soc B* 340:215–225.
- [36] Yohe LR, Brand P. 2018. Evolutionary ecology of chemosensation and its role in sensory drive. *Curr Zool* 64:525–533.
- [37] Cole GL. 2013. Lost in translation: Adaptation of mating signals in changing environments. *Springer Sci Rev* 1(1–2):25–40.
- [38] Hounam RF, Black A, Walsh M. 1971. The deposition of aerosol particles in the nasopharyngeal region of the human respiratory tract. *J Aerosol Sci* 2:47–61.
- [39] Kesavanathan J, Bascom R, Swift DL. 1998. The effect of nasal passage characteristics on particle deposition. *J Aerosol Med* 11:27–39.
- [40] Guilmette RA, Cheng YS, Yeh HC, Swift DL. 1994. Deposition of 0.005–12  $\mu$ m monodisperse particles in a computer-milled, MRI-based nasal airway replica. *Inhal Toxicol* 6:395–399.
- [41] Schroeter JD, Garcia GJ, Kimbell JS. 2011. Effects of surface smoothness on inertial particle deposition in human nasal models. *J Aerosol Sci* 42:52–63.
- [42] Gonda I, Gipps E. 1990. Model of disposition of drugs administered into the human nasal cavity. *Pharm Res* 7:69–75.
- [43] Ponikau JU, Sherris DA, Kephart GM, et al. 2005. Striking deposition of toxic eosinophil major basic protein in mucus: Implications for chronic rhinosinusitis. *J Allergy Clin Immunol* 116:362–369.
- [44] Kiaee M, Wachtel H, Noga ML, Martin AR, Finlay WH. 2019. An idealized geometry that mimics average nasal spray deposition in adults: A computational study. *Comput Biol Med* 107:206–217.
- [45] Shang Y, Inthavong K. 2019. Numerical assessment of ambient inhaled micron particle deposition in a human nasal cavity. *Int J Multiphase Flow* 1:109–115.
- [46] Schroeter JD, Kimbell JS, Asgharian B. 2006. Analysis of particle deposition in the turbinate and olfactory regions using a human nasal computational fluid dynamics model. *J Aerosol Med* 19:301–313.
- [47] Kublik H, Vidgren MT. 1998. Nasal delivery systems and their effect on deposition and absorption. *Adv Drug Deliv Rev* 29:157–177.
- [48] Itoh HG, Smaldone GC, Swift DL, Wagner HN Jr. 1985. Mechanisms of aerosol deposition in a nasal model. *J Aerosol Sci* 16:529–534.
- [49] Garcia GJ, Schroeter JD, Kimbell JS. 2015. Olfactory deposition of inhaled nanoparticles in humans. *Inhal Toxicol* 27:394–403.
- [50] Zhao K, Scherer PW, Hajiloo SA, Dalton P. 2004. Effect of anatomy on human nasal air flow and odorant transport patterns: Implications for olfaction. *Chem Senses* 29:365–379.
- [51] Maier W. 1993. Cranial morphology of the therian common ancestor, as suggested by the adaptations of neonate marsupials. In: Szalay FS, Novacek MJ, McKenna MC, editors. *Mammal phylogeny*, New York: Springer. p 165–181.
- [52] Yang GC, Scherer PW, Mozell MM. 2007. Modeling inspiratory and expiratory steady-state velocity fields in the Sprague-Dawley rat nasal cavity. *Chem Senses* 32:215–223.
- [53] Eiting TP, Smith TD, Perot JB, Dumont ER. 2014. The role of the olfactory recess in olfactory airflow. *J Exp Biol* 217:1799–1803.
- [54] Smith TD, Craven BA, Engel SM, Bonar CJ, DeLeon VB. 2019. Nasal airflow in the pygmy slow loris (*Nycticebus pygmaeus*) based on a combined histological, computed tomographic and computational fluid dynamics methodology. *J Exp Biol* 222:jeb207605.
- [55] Craven BA, Paterson EG, Settles GS. 2010. The fluid dynamics of canine olfaction: Unique nasal airflow patterns as an explanation of macrosmia. *J Roy Soc Interface* 7:933–943.

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