

The evolution of sweet taste perception in hummingbirds

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Parallel Sensory Universes







Chemosensory receptors vary in number



2,000

TAAR

6 (3)

3 (6)

5 (4)

15 (1)

17 (2)

2 (2)

17 (9)

22 (0)

4 (1)

3 (2)

6 (1)

13 (6)

109

(10)

100

0

OR

388 (414)

399 (414)

(328)

(508)

977

(294)

(278)

348 (370)

(614)

300 (133)

326 (280)

063

1152

1024

86 (39)

1259

1,000



800

0

0 (20)

0(17)

0 (11)

0 (9)

0 (16)

0 (0)

249

18 (29)

44 (8)

86 (79)

15 (112)

V2R

79 (142)

VIR

400

187 (121)

(579)

5 (115)

0 (116)

106 (66)

8 (33)

270

0 (0)

21 (2)

1(0)

2 (0)

40 (45)

98 (30)



V2R	TIR	T2R
400	05 L	0 40
	3 (0)	25 (11)
	3 (0)	24 (13)
	3 (0)	26 (14)
121 (158)	3 (0)	35 (6)
79 (142)	3 (0)	37 (5)
	3 (0)	16 (5)
	3 (?)	19 (15)
5 (79)	3 (0)	29 (5)
112)	?	?
	2 (0)	3 (0)
(448)	0 (0)	52 (12)
)	5 (0)	4 (0)
)	1 (0)	4 (0)

Nei, Niimura and Nozawa, Nature Reviews Genetics 2008



Multimodal taste buds



Five taste modalities



Ion channels

G-protein coupled receptors

T2Rs

T1Rs



The T1R family mediates and savory and sweet tastes

Umami

Sweet





T1R1 = umam T1R2 = sweet T1R3 = share

T1Rs loss linked to diet



Bird diet diversity



T1R2 loss in birds



T1R1 = umamiT1R2 = sweetT1R3 = shared

1.T1R2 is lost in birds

2. T1R2 is required for sweet perception

3. How do nectar-feeding birds detect sweet?

Erythritol preference in captivity

mean bout length, seconds (± SE)

sucrose



Rapid discrimination





If T1R2 is lost in birds, what functions as the sweet receptor?

Hypothesis 1: T1R3 acts as the sweet taste receptor by forming a homodimer



Hypothesis 2: T1R1 and T1R3 are no longer merely functioning as the umami taste receptor but have acquired the ability to detect carbohydrates

Hypothesis 3: Hummingbirds detect carbohydrates via a non-T1R-mediated method

T1R1 = umamiT1R2 = sweetT1R3 = shared

Cloning bird T1Rs



Chicken T1R cloning





NNNNNNNNNNNNNNNNNNNNNNNNN



5

T1R1 = umamiT1R2 = sweetT1R3 = shared

EXON 6

Functional assays of cloned T1Rs in tissue culture



T1R function in mammals



Hummingbird T1Rs respond differently



T1R1/T1R3 dose response







T1R3 Venus Fly Trap Chimeras









19 key residues identified









Preferred solutions elicit long bouts



Hummingbirds respond to T1R1/T1R3 agonists



T1R1/T1R3 agonists

test stimuli 🖂 sucrose

Evolution of a novel vertebrate sweet receptor

 T1R2 was lost early in birds, perhaps in carnivorous dinosaurian ancestors

..... yet nectar-feeders regained sweet perception

- Hummingbird carbohydrate detection occurs via widespread mutation of T1R1/T1R3
- Recognition properties of T1R1/T1R3 instruct hummingbird taste behavior in the wild



T1R1 = umamiT1R2 = sweetT1R3 = shared

Acknowledgements

<u>Yasuka Toda, Yoshiro Ishimaru</u> Tomoya Nakagita, Takumi Misaka and Keiko Abe

Evolution of Sensory Systems Research Group

Glenn Cockburn Daniel Mendez Aranda Julia Cramer Qiaoyi Liang Meng-Ching Ko

Collaborators

Scott Edwards, Simon Sin, Tim Sackton (Harvard) Kirk Klasing (UC Davis) Mary O'Connell (Leeds) Concord Field Station (Harvard), Lytle field station (BYU) Sungbo Cho and Eugeni Roura (University of Queensland) Pablo Oteiza (Harvard, Max Planck for Ornithology) Tom Smith, Brenda Larison (UCLA) Bill Buttemer, Alejandro Rico-Guevara (Deakin University, Australia)

Tissue collection: Wildlife Care Lindsey Wildlife Hospital, Holly Ernest (UC Davis), Michelle Hawkins (UC Davis), Pedro Ramirez and Ivo Ros (CFS Harvard) (OEB), Flavia Termignoni (UNAM) **Funding: NSF DDIG, Putnam (OEB), Sigma Xi, SICB, Frank Chapman (AMNH), MBB (Mind, Brain and Behavior, Harvard), OEB student research grants, Blake-Nuttall Ornithological Club**



