

Trace amine receptor (version 2019.4) in the IUPHAR/BPS Guide to Pharmacology Database

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Abstract

Trace amine-associated receptors were discovered from a search for novel 5-HT receptors [9], where 15 mammalian orthologues were identified and divided into two families. The TA₁ receptor (**nomenclature as agreed by the NC-IUPHAR Subcommittee for the Trace amine receptor [53]**) has affinity for the endogenous trace amines **tyramine**, **β-phenylethylamine** and **octopamine** in addition to the classical amine **dopamine** [9]. Emerging evidence suggests that TA₁ is a modulator of monoaminergic activity in the brain [90] with TA₁ and dopamine D₂ receptors shown to form constitutive heterodimers when co-expressed [28]. In addition to trace amines, receptors can be activated by amphetamine-like psychostimulants, and endogenous thyronamines.

Contents

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Database links

Trace amine receptor

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Introduction to Trace amine receptor

<http://www.guidetopharmacology.org/GRAC/FamilyIntroductionForward?familyId=64>

Receptors

TA₁ receptor

<http://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=364>

References

1. Achat-Mendes C, Lynch LJ, Sullivan KA, Vallender EJ and Miller GM. (2012) Augmentation of methamphetamine-induced behaviors in transgenic mice lacking the trace amine-associated receptor 1. *Pharmacol. Biochem. Behav.* **101**: 201-7 [[PMID:22079347](#)]
2. Adriaenssens A, Lam BY, Billing L, Skeffington K, Sewing S, Reimann F and Gribble F. (2015) A Transcriptome-Led Exploration of Molecular Mechanisms Regulating Somatostatin-Producing D-Cells in the Gastric Epithelium. *Endocrinology* **156**: 3924-36 [[PMID:26241122](#)]
3. Alvarsson A, Zhang X, Stan TL, Schintu N, Kadkhodaei B, Millan MJ, Perlmann T and Svenningsson P. (2015) Modulation by Trace Amine-Associated Receptor 1 of Experimental Parkinsonism, L-DOPA Responsivity, and Glutamatergic Neurotransmission. *J. Neurosci.* **35**: 14057-69 [[PMID:26468205](#)]
4. Axelrod J and Saavedra JM. (1977) Octopamine. *Nature* **265**: 501-4 [[PMID:13310](#)]
5. Babusyte A, Kotthoff M, Fiedler J and Krautwurst D. (2013) Biogenic amines activate blood leukocytes via trace amine-associated receptors TAAR1 and TAAR2. *J. Leukoc. Biol.* **93**: 387-94 [[PMID:23315425](#)]
6. Barak LS, Salahpour A, Zhang X, Masri B, Sotnikova TD, Ramsey AJ, Violin JD, Lefkowitz RJ, Caron MG and Gainetdinov RR. (2008) Pharmacological characterization of membrane-expressed human trace amine-associated receptor 1 (TAAR1) by a bioluminescence resonance energy transfer cAMP biosensor. *Mol. Pharmacol.* **74**: 585-594 [[PMID:18524885](#)]
7. Barger G and Dale HH. (1910) Chemical structure and sympathomimetic action of amines. *J. Physiol. (Lond.)* **41**: 19-59 [[PMID:16993040](#)]
8. Berry MD. (2007) The potential of trace amines and their receptors for treating neurological and psychiatric diseases. *Rev Recent Clin Trials* **2**: 3-19 [[PMID:18473983](#)]
9. Borowsky B, Adham N, Jones KA, Raddatz R, Artyomyshyn R, Ogozalek KL, Durkin MM, Lakhani PP, Bonini JA and Pathirana S *et al.*. (2001) Trace amines: identification of a family of mammalian G protein-coupled receptors. *Proc. Natl. Acad. Sci. U.S.A.* **98**: 8966-71 [[PMID:11459929](#)]
10. Bowsher RR and Henry DP. (1983) Decarboxylation of p-tyrosine: a potential source of p-tyramine in mammalian tissues. *J. Neurochem.* **40**: 992-1002 [[PMID:6131938](#)]
11. Bradaia A, Trube G, Stalder H, Norcross RD, Ozmen L, Wettstein JG, Pinard A, Buchy D, Gassmann M and Hoener MC *et al.*. (2009) The selective antagonist EPPTB reveals TAAR1-mediated regulatory mechanisms in dopaminergic neurons of the mesolimbic system. *Proc. Natl. Acad. Sci. U.S.A.* **106**: 20081-6 [[PMID:19892733](#)]
12. Branchek TA and Blackburn TP. (2003) Trace amine receptors as targets for novel therapeutics: legend, myth and fact. *Curr Opin Pharmacol* **3**: 90-7 [[PMID:12550748](#)]
13. Brier ME, Bowsher RR, Mayer PR and Henry DP. (1991) Conversion of p-tyrosine to p-tyramine in the isolated perfused rat kidney: modulation by perfusate concentrations of p-tyrosine. *Life Sci* **48**: 901-907 [[PMID:1997791](#)]
14. Bunzow JR, Sonders MS, Arttamangkul S, Harrison LM, Zhang G, Quigley DI, Darland T, Suchland KL, Pasumamula S and Kennedy JL *et al.*. (2001) Amphetamine, 3,4-methylenedioxymethamphetamine, lysergic acid diethylamide, and metabolites of the catecholamine neurotransmitters are agonists of a rat trace amine receptor. *Mol. Pharmacol.* **60**: 1181-8 [[PMID:11723224](#)]
15. Chaytor JP, Crathorne B and Saxby MJ. (1975) The identification and significance of 2-phenylethylamine in foods. *J. Sci. Food Agric.* **26**: 593-8 [[PMID:1160357](#)]
16. Chiellini G, Frascarelli S, Ghelardoni S, Carnicelli V, Tobias SC, DeBarber A, Brogioni S, Ronca-Testoni S, Cerbai E and Grandy DK *et al.*. (2007) Cardiac effects of 3-iodothyronamine: a new aminergic system modulating cardiac function. *FASEB J.* **21**: 1597-608 [[PMID:17284482](#)]
17. Cichero E, Espinoza S, Gainetdinov RR, Brasili L and Fossa P. (2013) Insights into the structure and pharmacology of the human trace amine-associated receptor 1 (hTAAR1): homology modelling and

- docking studies. *Chem Biol Drug Des* **81**: 509-16 [PMID:22883051]
- 18. Cisneros IE and Ghorpade A. (2014) Methamphetamine and HIV-1-induced neurotoxicity: role of trace amine associated receptor 1 cAMP signaling in astrocytes. *Neuropharmacology* **85**: 499-507 [PMID:24950453]
 - 19. D'Andrea G, Terrazzino S, Fortin D, Farruggio A, Rinaldi L and Leon A. (2003) HPLC electrochemical detection of trace amines in human plasma and platelets and expression of mRNA transcripts of trace amine receptors in circulating leukocytes. *Neurosci. Lett.* **346**: 89-92 [PMID:12850555]
 - 20. Dale HH and Dixon WE. (1909) The action of pressor amines produced by putrefaction. *J. Physiol. (Lond.)* **39**: 25-44 [PMID:16992970]
 - 21. Davenport AP. (2003) Peptide and trace amine orphan receptors: prospects for new therapeutic targets. *Curr Opin Pharmacol* **3**: 127-34 [PMID:12681233]
 - 22. David JC, Dairman W and Udenfriend S. (1974) Decarboxylation to tyramine: a major route of tyrosine metabolism in mammals. *Proc. Natl. Acad. Sci. U.S.A.* **71**: 1771-5 [PMID:4525291]
 - 23. Di Cara B, Maggio R, Aloisi G, Rivet JM, Lundius EG, Yoshitake T, Svenningsson P, Brocco M, Gobert A and De Groote L *et al.*. (2011) Genetic deletion of trace amine 1 receptors reveals their role in auto-inhibiting the actions of ecstasy (MDMA). *J. Neurosci.* **31**: 16928-40 [PMID:22114263]
 - 24. Duan J, Martinez M, Sanders AR, Hou C, Saitou N, Kitano T, Mowry BJ, Crowe RR, Silverman JM and Levinson DF *et al.*. (2004) Polymorphisms in the trace amine receptor 4 (TRAR4) gene on chromosome 6q23.2 are associated with susceptibility to schizophrenia. *Am. J. Hum. Genet.* **75**: 624-38 [PMID:15329799]
 - 25. Durden DA and Philips SR. (1980) Kinetic measurements of the turnover rates of phenylethylamine and tryptamine in vivo in the rat brain. *J Neurochem* **34**: 1725-1732 [PMID:7381498]
 - 26. Espinoza S, Ghisi V, Emanuele M, Leo D, Sukhanov I, Sotnikova TD, Chieregatti E and Gainetdinov RR. (2015) Postsynaptic D2 dopamine receptor supersensitivity in the striatum of mice lacking TAAR1. *Neuropharmacology* **93**: 308-13 [PMID:25721394]
 - 27. Espinoza S, Lignani G, Caffino L, Maggi S, Sukhanov I, Leo D, Mus L, Emanuele M, Ronzitti G and Harmeier A *et al.*. (2015) TAAR1 Modulates Cortical Glutamate NMDA Receptor Function. *Neuropsychopharmacology* **40**: 2217-27 [PMID:25749299]
 - 28. Espinoza S, Salahpour A, Masri B, Sotnikova TD, Messa M, Barak LS, Caron MG and Gainetdinov RR. (2011) Functional interaction between trace amine-associated receptor 1 and dopamine D2 receptor. *Mol. Pharmacol.* **80**: 416-25 [PMID:21670104]
 - 29. Fehler M, Broadley KJ, Ford WR and Kidd EJ. (2010) Identification of trace-amine-associated receptors (TAAR) in the rat aorta and their role in vasoconstriction by β -phenylethylamine. *Naunyn Schmiedebergs Arch. Pharmacol.* **382**: 385-98 [PMID:20809238]
 - 30. Foord SM, Bonner TI, Neubig RR, Rosser EM, Pin JP, Davenport AP, Spedding M and Harmar AJ. (2005) International Union of Pharmacology. XLVI. G protein-coupled receptor list. *Pharmacol. Rev.* **57**: 279-88 [PMID:15914470]
 - 31. Frascarelli S, Ghelardoni S, Chiellini G, Vargiu R, Ronca-Testoni S, Scanlan TS, Grandy DK and Zucchi R. (2008) Cardiac effects of trace amines: pharmacological characterization of trace amine-associated receptors. *Eur. J. Pharmacol.* **587**: 231-6 [PMID:18486124]
 - 32. Galley G, Beurier A, Décoret G, Goergler A, Hutter R, Mohr S, Pähler A, Schmid P, Türk D and Unger R *et al.*. (2016) Discovery and Characterization of 2-Aminooxazolines as Highly Potent, Selective, and Orally Active TAAR1 Agonists. *ACS Med Chem Lett* **7**: 192-7 [PMID:26985297]
 - 33. Galley G, Stalder H, Goergler A, Hoener MC and Norcross RD. (2012) Optimisation of imidazole compounds as selective TAAR1 agonists: discovery of RO5073012. *Bioorg. Med. Chem. Lett.* **22**: 5244-8 [PMID:22795332]
 - 34. Gloriam DE, Bjarnadóttir TK, Schiöth HB and Fredriksson R. (2005) High species variation within the repertoire of trace amine receptors. *Ann. N. Y. Acad. Sci.* **1040**: 323-7 [PMID:15891052]
 - 35. Gozal EA, O'Neill BE, Sawchuk MA, Zhu H, Halder M, Chou CC and Hochman S. (2014) Anatomical and functional evidence for trace amines as unique modulators of locomotor function in the mammalian spinal

- cord. *Front Neural Circuits* **8**: 134 [PMID:25426030]
36. Grandy DK. (2007) Trace amine-associated receptor 1-Family archetype or iconoclast? *Pharmacol. Ther.* **116**: 355-90 [PMID:17888514]
37. Hannah P, Glover V and Sandler M. (1988) Tyramine in wine and beer. *Lancet* **1**: 879 [PMID:2895380]
38. Hart ME, Suchland KL, Miyakawa M, Bunzow JR, Grandy DK and Scanlan TS. (2006) Trace amine-associated receptor agonists: synthesis and evaluation of thyronamines and related analogues. *J. Med. Chem.* **49**: 1101-12 [PMID:16451074]
39. Hashiguchi Y and Nishida M. (2007) Evolution of trace amine associated receptor (TAAR) gene family in vertebrates: lineage-specific expansions and degradations of a second class of vertebrate chemosensory receptors expressed in the olfactory epithelium. *Mol. Biol. Evol.* **24**: 2099-107 [PMID:17634392]
40. Hu LA, Zhou T, Ahn J, Wang S, Zhou J, Hu Y and Liu Q. (2009) Human and mouse trace amine-associated receptor 1 have distinct pharmacology towards endogenous monoamines and imidazoline receptor ligands. *Biochem. J.* **424**: 39-45 [PMID:19725810]
41. Kleinau G, Pratzka J, Nürnberg D, Grüters A, Führer-Sakel D, Krude H, Köhrle J, Schöneberg T and Biebermann H. (2011) Differential modulation of Beta-adrenergic receptor signaling by trace amine-associated receptor 1 agonists. *PLoS ONE* **6**: e27073 [PMID:22073124]
42. Lam VM, Espinoza S, Gerasimov AS, Gainetdinov RR and Salahpour A. (2015) In-vivo pharmacology of Trace-Amine Associated Receptor 1. *Eur. J. Pharmacol.* **763**: 136-42 [PMID:26093041]
43. Leo D, Mus L, Espinoza S, Hoener MC, Sotnikova TD and Gainetdinov RR. (2014) Taar1-mediated modulation of presynaptic dopaminergic neurotransmission: role of D2 dopamine autoreceptors. *Neuropharmacology* **81**: 283-91 [PMID:24565640]
44. Lewin AH. (2006) Receptors of mammalian trace amines. *AAPS J* **8**: E138-45 [PMID:16584120]
45. Lewin AH, Miller GM and Gilmour B. (2011) Trace amine-associated receptor 1 is a stereoselective binding site for compounds in the amphetamine class. *Bioorg. Med. Chem.* **19**: 7044-8 [PMID:22037049]
46. Lewin AH, Navarro HA and Mascarella SW. (2008) Structure-activity correlations for beta-phenethylamines at human trace amine receptor 1. *Bioorg. Med. Chem.* **16**: 7415-23 [PMID:18602830]
47. Liberles SD and Buck LB. (2006) A second class of chemosensory receptors in the olfactory epithelium. *Nature* **442**: 645-650 [PMID:16878137]
48. Lindemann L, Ebeling M, Kratochwil NA, Bunzow JR, Grandy DK and Hoener MC. (2005) Trace amine-associated receptors form structurally and functionally distinct subfamilies of novel G protein-coupled receptors. *Genomics* **85**: 372-85 [PMID:15718104]
49. Lindemann L and Hoener MC. (2005) A renaissance in trace amines inspired by a novel GPCR family. *Trends Pharmacol. Sci.* **26**: 274-81 [PMID:15860375]
50. Lindemann L, Meyer CA, Jeanneau K, Bradaia A, Ozmen L, Bluethmann H, Bettler B, Wettstein JG, Borroni E and Moreau JL et al.. (2008) Trace amine-associated receptor 1 modulates dopaminergic activity. *J. Pharmacol. Exp. Ther.* **324**: 948-56 [PMID:18083911]
51. Liu JF, Thorn DA, Zhang Y and Li JX. (2016) Effects of Trace Amine-associated Receptor 1 Agonists on the Expression, Reconsolidation, and Extinction of Cocaine Reward Memory. *Int. J. Neuropsychopharmacol.* **19**: [PMID:26822713]
52. Lynch LJ, Sullivan KA, Vallender EJ, Rowlett JK, Platt DM and Miller GM. (2013) Trace amine associated receptor 1 modulates behavioral effects of ethanol. *Subst Abuse* **7**: 117-26 [PMID:23861588]
53. Maguire JJ, Parker WA, Foord SM, Bonner TI, Neubig RR and Davenport AP. (2009) International Union of Pharmacology. LXII. Recommendations for trace amine receptor nomenclature. *Pharmacol. Rev.* **61**: 1-8 [PMID:19325074]
54. Miller GM. (2011) The emerging role of trace amine-associated receptor 1 in the functional regulation of monoamine transporters and dopaminergic activity. *J. Neurochem.* **116**: 164-76 [PMID:21073468]
55. Miller GM, Verrico CD, Jassen A, Konar M, Yang H, Panas H, Bahn M, Johnson R and Madras BK. (2005) Primate trace amine receptor 1 modulation by the dopamine transporter. *J. Pharmacol. Exp. Ther.* **313**: 983-94 [PMID:15764732]
56. Miyakawa M and Scanlan TS. (2006) Synthesis of [¹²⁵I]-, [²H]-, and [³H]-labelled 3-iodothyronamine

- (T1AM). *Synthetic Communications* **36**: 891-902
57. Navarro HA, Gilmour BP and Lewin AH. (2006) A rapid functional assay for the human trace amine-associated receptor 1 based on the mobilization of internal calcium. *J Biomol Screen* **11**: 688-93 [PMID:16831861]
 58. Nelson DA, Tolbert MD, Singh SJ and Bost KL. (2007) Expression of neuronal trace amine-associated receptor (Taar) mRNAs in leukocytes. *J Neuroimmunol.* **192**: 21-30 [PMID:17900709]
 59. Pae CU, Drago A, Kim JJ, Patkar AA, Jun TY, Lee C, Mandelli L, De Ronchi D, Paik IH and Serretti A. (2008) TAAR6 variation effect on clinic presentation and outcome in a sample of schizophrenic in-patients: an open label study. *Eur. Psychiatry* **23**: 390-5 [PMID:18583103]
 60. Pae CU, Yu HS, Amann D, Kim JJ, Lee CU, Lee SJ, Jun TY, Lee C, Paik IH and Patkar AA et al.. (2008) Association of the trace amine associated receptor 6 (TAAR6) gene with schizophrenia and bipolar disorder in a Korean case control sample. *J Psychiatr Res* **42**: 35-40 [PMID:17097106]
 61. Paterson IA, Juorio AV and Boulton AA. (1990) 2-Phenylethylamine: a modulator of catecholamine transmission in the mammalian central nervous system? *J. Neurochem.* **55**: 1827-37 [PMID:2172461]
 62. Pei Y, Asif-Malik A and Canales JJ. (2016) Trace Amines and the Trace Amine-Associated Receptor 1: Pharmacology, Neurochemistry, and Clinical Implications. *Front Neurosci* **10**: 148 [PMID:27092049]
 63. Pei Y, Mortas P, Hoener MC and Canales JJ. (2015) Selective activation of the trace amine-associated receptor 1 decreases cocaine's reinforcing efficacy and prevents cocaine-induced changes in brain reward thresholds. *Prog. Neuropsychopharmacol. Biol. Psychiatry* **63**: 70-5 [PMID:26048337]
 64. Piehl S, Hoefig CS, Scanlan TS and Köhrle J. (2011) Thyronamines--past, present, and future. *Endocr. Rev.* **32**: 64-80 [PMID:20880963]
 65. Raab S, Wang H, Uhles S, Cole N, Alvarez-Sánchez R, Künnecke B, Ullmer C, Matile H, Bedoucha M and Norcross RD et al.. (2016) Incretin-like effects of small molecule trace amine-associated receptor 1 agonists. *Mol Metab* **5**: 47-56 [PMID:26844206]
 66. Reese EA, Bunzow JR, Arttamangkul S, Sonders MS and Grandy DK. (2007) Trace amine-associated receptor 1 displays species-dependent stereoselectivity for isomers of methamphetamine, amphetamine, and para-hydroxyamphetamine. *J. Pharmacol. Exp. Ther.* **321**: 178-86 [PMID:17218486]
 67. Reese EA, Norimatsu Y, Grandy MS, Suchland KL, Bunzow JR and Grandy DK. (2014) Exploring the determinants of trace amine-associated receptor 1's functional selectivity for the stereoisomers of amphetamine and methamphetamine. *J. Med. Chem.* **57**: 378-90 [PMID:24354319]
 68. Regard JB, Kataoka H, Cano DA, Camerer E, Yin L, Zheng YW, Scanlan TS, Hebrok M and Coughlin SR. (2007) Probing cell type-specific functions of Gi in vivo identifies GPCR regulators of insulin secretion. *J. Clin. Invest.* **117**: 4034-43 [PMID:17992256]
 69. Revel FG, Meyer CA, Bradaia A, Jeanneau K, Calcagno E, André CB, Haenggi M, Miss MT, Galley G and Norcross RD et al.. (2012) Brain-specific overexpression of trace amine-associated receptor 1 alters monoaminergic neurotransmission and decreases sensitivity to amphetamine. *Neuropsychopharmacology* **37**: 2580-92 [PMID:22763617]
 70. Revel FG, Moreau JL, Gainetdinov RR, Bradaia A, Sotnikova TD, Mory R, Durkin S, Zbinden KG, Norcross R and Meyer CA et al.. (2011) TAAR1 activation modulates monoaminergic neurotransmission, preventing hyperdopaminergic and hypoglutamatergic activity. *Proc. Natl. Acad. Sci. U.S.A.* **108**: 8485-90 [PMID:21525407]
 71. Revel FG, Moreau JL, Gainetdinov RR, Ferragud A, Velázquez-Sánchez C, Sotnikova TD, Morairty SR, Harmeier A, Groebke Zbinden K and Norcross RD et al.. (2012) Trace amine-associated receptor 1 partial agonism reveals novel paradigm for neuropsychiatric therapeutics. *Biol. Psychiatry* **72**: 934-42 [PMID:22705041]
 72. Revel FG, Moreau JL, Pouzet B, Mory R, Bradaia A, Buchy D, Metzler V, Chaboz S, Groebke Zbinden K and Galley G et al.. (2013) A new perspective for schizophrenia: TAAR1 agonists reveal antipsychotic- and antidepressant-like activity, improve cognition and control body weight. *Mol. Psychiatry* **18**: 543-56 [PMID:22641180]
 73. Roeder T. (2005) Tyramine and octopamine: ruling behavior and metabolism. *Annu. Rev. Entomol.* **50**:

447-77 [PMID:15355245]

74. Scanlan TS, Suchland KL, Hart ME, Chiellini G, Huang Y, Kruzich PJ, Frascarelli S, Crossley DA, Bunzow JR and Ronca-Testoni S *et al.*. (2004) 3-Iodothyronamine is an endogenous and rapid-acting derivative of thyroid hormone. *Nat. Med.* **10**: 638-42 [PMID:15146179]
75. Schöneberg T, Hofreiter M, Schulz A and Römler H. (2007) Learning from the past: evolution of GPCR functions. *Trends Pharmacol. Sci.* **28**: 117-21 [PMID:17280721]
76. Smith SB, Maixner DW, Fillingim RB, Slade G, Gracely RH, Ambrose K, Zaykin DV, Hyde C, John S and Tan K *et al.*. (2012) Large candidate gene association study reveals genetic risk factors and therapeutic targets for fibromyalgia. *Arthritis Rheum.* **64**: 584-93 [PMID:21905019]
77. Sotnikova TD, Caron MG and Gainetdinov RR. (2009) Trace amine-associated receptors as emerging therapeutic targets. *Mol. Pharmacol.* **76**: 229-35 [PMID:19389919]
78. Sotnikova TD, Zorina OI, Ghisi V, Caron MG and Gainetdinov RR. (2008) Trace amine associated receptor 1 and movement control. *Parkinsonism Relat. Disord.* **14 Suppl 2**: S99-102 [PMID:18585080]
79. Stalder H, Hoener MC and Norcross RD. (2011) Selective antagonists of mouse trace amine-associated receptor 1 (mTAAR1): discovery of EPPTB (RO5212773). *Bioorg. Med. Chem. Lett.* **21**: 1227-31 [PMID:21237643]
80. Sukhanov I, Espinoza S, Yakovlev DS, Hoener MC, Sotnikova TD and Gainetdinov RR. (2014) TAAR1-dependent effects of apomorphine in mice. *Int. J. Neuropsychopharmacol.* **17**: 1683-93 [PMID:24925023]
81. Szumska J, Qatato M, Rehders M, Führer D, Biebermann H, Grandy DK, Köhrle J and Brix K. (2015) Trace Amine-Associated Receptor 1 Localization at the Apical Plasma Membrane Domain of Fisher Rat Thyroid Epithelial Cells Is Confined to Cilia. *Eur Thyroid J* **4**: 30-41 [PMID:26601071]
82. Tan ES, Groban ES, Jacobson MP and Scanlan TS. (2008) Toward deciphering the code to aminergic G protein-coupled receptor drug design. *Chem. Biol.* **15**: 343-53 [PMID:18420141]
83. Tan ES, Miyakawa M, Bunzow JR, Grandy DK and Scanlan TS. (2007) Exploring the structure-activity relationship of the ethylamine portion of 3-iodothyronamine for rat and mouse trace amine-associated receptor 1. *J. Med. Chem.* **50**: 2787-98 [PMID:17497842]
84. Tan ES, Naylor JC, Groban ES, Bunzow JR, Jacobson MP, Grandy DK and Scanlan TS. (2009) The molecular basis of species-specific ligand activation of trace amine-associated receptor 1 (TAAR(1)). *ACS Chem. Biol.* **4**: 209-20 [PMID:19256523]
85. Vanti WB, Muglia P, Nguyen T, Cheng R, Kennedy JL, George SR and O'Dowd BF. (2003) Discovery of a null mutation in a human trace amine receptor gene. *Genomics* **82**: 531-536 [PMID:14559210]
86. Wainscott DB, Little SP, Yin T, Tu Y, Rocco VP, He JX and Nelson DL. (2007) Pharmacologic characterization of the cloned human trace amine-associated receptor1 (TAAR1) and evidence for species differences with the rat TAAR1. *J. Pharmacol. Exp. Ther.* **320**: 475-85 [PMID:17038507]
87. Wasik AM, Millan MJ, Scanlan T, Barnes NM and Gordon J. (2012) Evidence for functional trace amine associated receptor-1 in normal and malignant B cells. *Leuk. Res.* **36**: 245-9 [PMID:22036195]
88. Wolinsky TD, Swanson CJ, Smith KE, Zhong H, Borowsky B, Seeman P, Brancheck T and Gerald CP. (2007) The Trace Amine 1 receptor knockout mouse: an animal model with relevance to schizophrenia. *Genes Brain Behav.* **6**: 628-39 [PMID:17212650]
89. Xie Z and Miller GM. (2008) Beta-phenylethylamine alters monoamine transporter function via trace amine-associated receptor 1: implication for modulatory roles of trace amines in brain. *J. Pharmacol. Exp. Ther.* **325**: 617-28 [PMID:18182557]
90. Xie Z and Miller GM. (2009) Trace amine-associated receptor 1 as a monoaminergic modulator in brain. *Biochem. Pharmacol.* **78**: 1095-104 [PMID:19482011]
91. Xie Z, Westmoreland SV, Bahn ME, Chen GL, Yang H, Vallender EJ, Yao WD, Madras BK and Miller GM. (2007) Rhesus monkey trace amine-associated receptor 1 signaling: enhancement by monoamine transporters and attenuation by the D2 autoreceptor in vitro. *J. Pharmacol. Exp. Ther.* **321**: 116-27 [PMID:17234900]
92. Xie Z, Westmoreland SV and Miller GM. (2008) Modulation of monoamine transporters by common biogenic amines via trace amine-associated receptor 1 and monoamine autoreceptors in human embryonic

- kidney 293 cells and brain synaptosomes. *J. Pharmacol. Exp. Ther.* **325**: 629-40 [PMID:18310473]
93. Zucchi R, Chiellini G, Scanlan TS and Grandy DK. (2006) Trace amine-associated receptors and their ligands. *Br. J. Pharmacol.* **149**: 967-78 [PMID:17088868]