



Universiteit
Leiden

The Netherlands

Sensing transport: label-free in vitro assays as an atTRACTive alternative for solute carrier transporter drug discovery

Sijben, H.J.

Citation

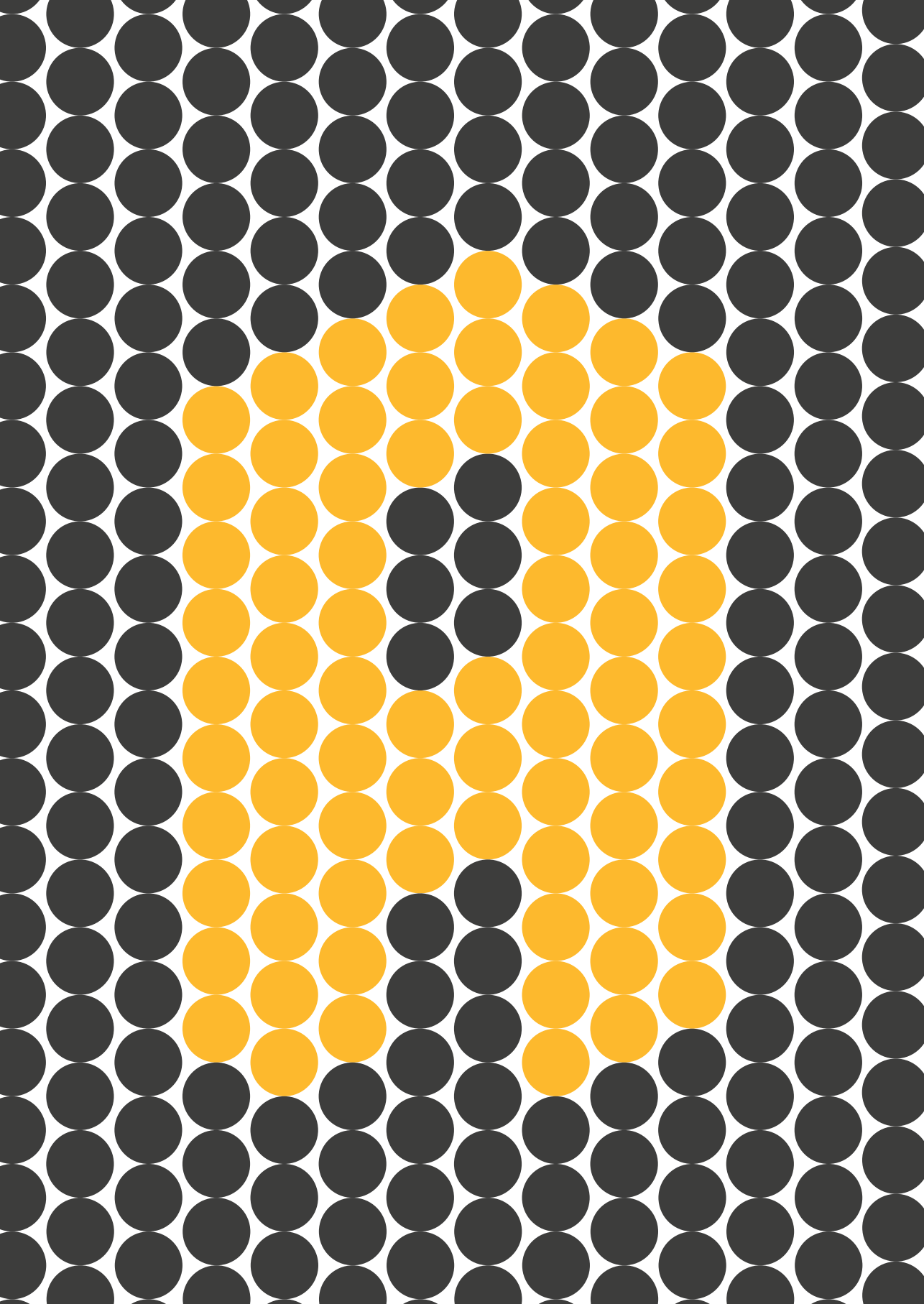
Sijben, H. J. (2022, November 23). *Sensing transport: label-free in vitro assays as an atTRACTive alternative for solute carrier transporter drug discovery*. Retrieved from <https://hdl.handle.net/1887/3487027>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/3487027>

Note: To cite this publication please use the final published version (if applicable).



APPENDIX

Table A.1–A.2

The tables in this section highlight the breadth of solute carrier (SLC) transporters that mediate the translocation of ligands/substrates that activate G protein-coupled receptors (GPCRs) (**Table A.1**) and that are co-transporters of Na⁺ (**Table A.2**).

Table A.1 – Affinity and potency values of endogenous substrates for various human solute carrier transporters and G protein-coupled receptors.

Solute carrier transporter (SLC)				Substrate				G protein-coupled receptor (GPCR)			
Gene	Protein	Affinity / activity	Comments	Mode of transport	Ref	Gene	Protein	Affinity / potency	Comments	Ref	
Nucleosides & nucleotides											
SLC28A2	CNT2	6–23 μM	K_m (^3H)ADE uptake, EP)	Influx	1	ADORA1	A ₁	100–310 nM	EC ₅₀ (cAMP assay)	2	
SLC28A3	CNT3	2.2–15 μM	K_m (^3H)ADE uptake, EP)	Influx	1	ADORA2A	A _{2A}	310–730 nM	EC ₅₀ (cAMP assay)	2	
SLC29A1	ENT1	32–82 μM	K_m (^3H)ADE uptake)	Influx / efflux	1	ADORA2B	A _{2B}	15,000 nM	EC ₅₀ (cAMP assay)	2	
SLC29A2	ENT2	49–140 μM	K_m (^3H)ADE uptake)	Influx / efflux	1	ADORA3	A ₃	290 nM	EC ₅₀ (cAMP assay)	2	
SLC29A3	ENT3	1,620–1,860 μM	K_m (^3H)ADE uptake, pH 5.5)	Influx / efflux	1						
SLC29A4	ENT4	780 μM	K_m (^3H)ADE uptake, pH 5.5)	Influx / efflux	1						
SLC17A9	VNUT	800 μM	K_m (^{32}P)ATP uptake)	Vesicular	3	P2YR1	P2Y ₁	17,700 nM	K_i (^3H)MRS2279 binding)	4	
						P2YR2	P2Y ₂	230 nM	EC ₅₀ (IP ₃ assay)	5	
						P2YR11	P2Y ₁₁	38,000 nM	EC ₅₀ (IP ₃ assay, cAMP assay)	6	
						P2YR12	P2Y ₁₂	690 nM	EC ₅₀ (cAMP assay)	7	
						P2YR13	P2Y ₁₃	4,200 nM	EC ₅₀ (IP ₃ assay)	8	
						GPR17	GPR17	37 nM	EC ₅₀ (cAMP assay)	9	
SLC17A9	VNUT		Transported *	Vesicular	3	P2YR1	P2Y ₁	920 nM	K_i (^3H)MRS2279 binding)	4	
						P2YR12	P2Y ₁₂	42 nM	EC ₅₀ (cAMP assay)	7	
						P2YR13	P2Y ₁₃	45–194 nM	EC ₅₀ (IP ₃ assay)	8	
SLC17A9	VNUT		Transported *	Vesicular	3	P2YR4	P2Y ₄	6,600 nM	EC ₅₀ (Ca ²⁺ assay)	10	
Monoamine neurotransmitters											
SLC18A3	VACHT	970 μM	K_m (^3H)ACh uptake)	Vesicular	11	CHRM1	M ₁	47 μM	K_i (^3H)NMS binding)	12	
SLC22A1	OCT1	1.17 μM	K_m (EP)	Influx / efflux	13	CHRM2	M ₂	0.3–47 μM	K_i (^3H)NMS binding)	12,14	
SLC22A2	OCT2	580 μM	IC ₅₀ (^3H)MPP ⁺ inhibition)	Influx / efflux	13	CHRM3	M ₃	4.2–29 μM	K_i (^3H)NMS binding)	12,14	
SLC22A4	OCTN1	1,000 μM	K_m (^3H)ACh uptake)	Influx	13	CHRM4	M ₄	5.1–32 μM	K_i (^3H)NMS binding)	12,14	
						CHRM5	M ₅	0.8 nM	K_i (^3H)NMS binding)	14	
SLC6A2	NET	0.1–0.7 μM	K_m (^3H)DA uptake)	Influx	15–17	ADRA2A	α_{2A}	2,600 nM	IC ₅₀ (^3H)MK912 binding)	18	
SLC6A3	DAT	1.2–2.5 μM	K_m (^3H)DA uptake)	Influx	16,19	ADRA2C	α_{2C}	3,200 nM	IC ₅₀ (^3H)MK912 binding)	18	
SLC18A1	VMAT1	3.8 μM	K_i (^3H)5-HT inhibition)	Vesicular	20	DRD1	D ₁	2,340 nM	K_i (^3H)SCH23390 binding)	21	
SLC18A2	VMAT2	1.4 μM	K_i (^3H)5-HT inhibition)	Vesicular	20	DRD2	D ₂	710 nM	K_i (^{125}I)iodosulpiride binding)	22	
SLC22A1	OCT1	487 μM	IC ₅₀ (^3H)5-HT inhibition)	Influx	13	DRD3	D ₃	29 nM	K_i (^{125}I)iodosulpiride binding)	22	
SLC22A2	OCT2	390–1,400 μM	K_m (^3H)DA uptake)	Influx	13	DRD4	D ₄	0.9–47 nM	K_i (^3H)spiperone binding)	23,24	
SLC22A3	OCT3	800–1,033 μM	K_m (^3H)DA uptake)	Influx	13,25	DRD5	D ₅	228 nM	K_i (^3H)SCH23390 binding)	21	
SLC29A4	PMAT	329–406 μM	K_m (^3H)DA uptake)	Influx	25,26	TAAR1	TA ₁	422 nM	K_i (^3H)tyramine binding)	27	
SLC6A2	NET	2.9–3.2 μM	K_m (^3H)EPI uptake)	Influx	15,17	ADRA1A	α_{1A}	600 nM	K_i (^{125}I)HEAT binding)	28	
SLC18A1	VMAT1	5.5 μM	K_i (^3H)5-HT inhibition)	Vesicular	20	ADRA1B	α_{1B}	400 nM	K_i (^{125}I)HEAT binding)	28	
SLC18A2	VMAT2	1.9 μM	K_i (^3H)5-HT inhibition)	Vesicular	20	ADRA1D	α_{1D}	56 nM	K_i (^{125}I)HEAT binding)	28	
SLC22A1	OCT1		Transported *	Influx	13	ADRA2A	α_{2A}	1,479 nM	K_i (^3H)MK912 binding)	29	
SLC22A2	OCT2	420 μM	K_m (^3H)EPI uptake)	Influx	13	ADRA2B	α_{2B}	6,309 nM	K_i (^3H)MK912 binding)	29	
SLC22A3	OCT3	240–458 μM	K_m (^3H)EPI uptake)	Influx	13,25	ADRA2C	α_{2C}	1,698 nM	K_i (^3H)MK912 binding)	29	
SLC29A4	PMAT	951–15,323 μM	K_m (^3H)EPI uptake)	Influx	25,26	ADRB1	β_1	3,970 nM	K_i (^{125}I)CYP binding)	30	
						ADRB2	β_2	735 nM	K_i (^{125}I)CYP binding)	30	
						ADRB3	β_3	126,000 nM	K_i (^{125}I)CYP binding)	30	
						DRD4	D ₄	14–240 nM	K_i (^3H)spiperone binding)	24	

Solute carrier transporter (SLC)				G protein-coupled receptor (GPCR)							
Gene	Protein	Affinity / activity	Comments	Mode of transport	Substrate	Gene	Protein	Affinity / potency	Comments	Ref	
SLC6A2	NET	0.3–0.7 μM	K _m (³ H)NE uptake)	Influx	Norepinephrine	ADRA1A	α _{1A}	990 nM	K _i (¹²⁵ I)HEAT binding)	26	
SLC6A3	DAT	20 μM	K _m (³ H)NE uptake)	Influx		ADRA1B	α _{1B}	680 nM	K _i (¹²⁵ I)HEAT binding)	28	
SLC18A1	VMAT1	14 μM	K _m (³ H)5-HT inhibition)	Vesicular		ADRA1D	α _{1D}	42 nM	K _i (¹²⁵ I)HEAT binding)	28	
SLC18A2	VMAT2	3.4 μM	K _m (³ H)5-HT inhibition)	Vesicular		ADRA2A	α _{2A}	1,995 nM	K _i (³ H)MK912 binding)	29	
SLC22A1	OCT1		<i>Transported*</i>	Influx		ADRA2B	α _{2B}	2,754 nM	K _i (³ H)MK912 binding)	29	
SLC22A2	OCT2	1,500–5,450 μM	K _m (³ H)NE uptake)	Influx		ADRA2C	α _{2C}	1,348 nM	K _i (³ H)MK912 binding)	28	
SLC22A3	OCT3	182–2,630 μM	K _m (³ H)NE uptake)	Influx		ADRB1	β ₁	3,570 nM	K _i (¹²⁵ I)CYP binding)	30	
SLC29A4	PMAT	1,078–2,606 μM	K _m (³ H)NE uptake)	Influx		ADRB2	β ₂	26,400 nM	K _i (¹²⁵ I)CYP binding)	30	
						ADRB3	β ₃	4,300 nM	K _i (¹²⁵ I)CYP binding)	30	
						DRD4	D ₄	33–1,324 nM	K _i (³ H)spiperone binding)	24	
					TAAR1	TA ₁	> 10,000 nM	K _i (³ H)tyramine binding)	33		
SLC6A4	SERT	0.5 μM	K _m (³ H)5-HT uptake)	Influx	Serotonin	5-HT1A	5-HT _{1A}	0.2 nM	K _i (³ H)8-OH-DPAT binding)	33	
SLC18A1	VMAT1	1.3 μM	K _m (³ H)5-HT uptake)	Vesicular		5-HT1B	5-HT _{1B}	4.3 nM	K _i (³ H)5-HT binding)	34	
SLC18A2	VMAT2	0.8 μM	K _m (³ H)5-HT uptake)	Vesicular		5-HT1D	5-HT _{1D}	3.9 nM	K _i (³ H)5-HT binding)	34	
SLC22A1	OCT1	197 μM	K _m (³ H)5-HT uptake)	Influx		5-HT1E	5-HT _{1E}	1.1 nM	K _i (³ H)5-HT binding)	35	
SLC22A2	OCT2	80–290 μM	K _m (³ H)5-HT uptake)	Influx		5-HT1F	5-HT _{1F}	10 nM	K _i (³ H)5-HT binding)	36	
SLC22A3	OCT3	900–988 μM	K _m (³ H)5-HT uptake)	Influx		5-HT1G	5-HT _{1G}	16 nM	K _i (³ H)ketanserin binding)	37	
SLC29A4	PMAT	114–283 μM	K _m (³ H)5-HT uptake)	Influx		5-HT2A	5-HT _{2A}	1.8 nM	K _i (³ H)mesulegine binding)	37	
						5-HT2B	5-HT _{2B}	5.8 nM	K _i (³ H)mesulegine binding)	37	
						5-HT2C	5-HT _{2C}	330–1,151 nM	K _i (³ H)mesulegine binding)	38	
						5-HT4	5-HT ₄	126 nM	K _i (³ H)GR113808 binding)	39	
SLC18A1	VMAT1	4,696 μM	K _m (³ H)5-HT inhibition)	Vesicular	Histamine	5-HT5A	5-HT _{5A}	65 nM	K _i (³ H)5-CT binding)	40	
SLC18A2	VMAT2	143 μM	K _m (³ H)5-HT inhibition)	Vesicular		5-HT5B	5-HT _{5B}	8.1 nM	K _i (³ H)5-HT binding)	41	
SLC22A1	OCT1	3,007 μM	IC ₅₀ (³ H)TEA inhibition)	Influx		5-HT7	5-HT ₇	3,000 nM	K _i (³ H)SCH23390 binding)	21	
SLC22A2	OCT2	940–1,300 μM	K _m (³ H)HIS uptake)	Influx		DRD1	D ₁	9,690 nM	K _i (³ H)SCH23390 binding)	21	
SLC22A3	OCT3	180–641 μM	K _m (³ H)HIS uptake)	Influx		DRD5	D ₅	> 6,000 nM	K _i (³ H)tyramine binding)	27	
SLC29A4	PMAT	4,379–10,471 μM	K _m (³ H)HIS uptake)	Influx		TAAR1	TA ₁	1,259 nM	K _i (³ H)tyramine binding)	42	
			<i>Transported*</i>			HRH1	H ₁	2,000–8,100 nM	K _i (¹²⁵ I)-APT binding)	43	
						HRH2	H ₂	15 nM	K _i (³ H)methylhistamine binding)	44	
						HRH3	H ₃	8.1 nM	K _i (³ H)histamine binding)	45	
						TAAR1	TA ₁	> 6,000 nM	K _i (³ H)tyramine binding)	27	
SLC29A4	GLUT1		<i>Transported*</i>	Influx	Melatonin	MTNR1A	MT ₁	0.2 nM	K _i (¹²⁵ I)iodometatonin binding)	47	
SLC15A1	PEPT1	600 μM	K _m (LC-MS/MS)	Influx / mito		MTNR1B	MT ₂	0.4 nM	K _i (¹²⁵ I)iodometatonin binding)	47	
SLC15A2	PEPT2	1,000 μM	K _m (LC-MS/MS)	Influx / mito	Trace amines						
SLC6A3	DAT	1.7–2.2 μM	K _m (³ H)tyramine uptake, EP)	Influx	Tyramine	TAAR1	TA ₁	34 nM	K _i (³ H)tyramine binding)	27	
SLC6A4	SERT	53 μM	K _m (³ H)tyramine uptake)	Influx							
SLC22A1	OCT1	107 μM	IC ₅₀ (³ H)TEA inhibition)	Influx							
SLC22A2	OCT2		<i>Transported*</i>	Influx / efflux							
SLC22A3	OCT3		<i>Transported*</i>	Influx							
SLC29A4	PMAT	238 μM	K _m (³ H)tyramine uptake)	Influx							

Solute carrier transporter (SLC)				G protein-coupled receptor (GPCR)							
Gene	Protein	Affinity / activity	Comments	Mode of transport	Ref	Substrate	Gene	Protein	Affinity / potency	Comments	Ref
Amino acids											
SLC1A1	EAAT3	62 μM	K_m (³ H]Glu uptake)	Influx	52	L-glutamate	CASR	CaR	~1,000 μM	EC ₅₀ (allosteric modulation of Ca ²⁺)	53,54
SLC1A2	EAAT2	97 μM	K_m (³ H]Glu uptake)	Influx	52		GRM1	mGlu ₁	40–184 μM	EC ₅₀ (Ca ²⁺ , IP ₃ assay)	55,56
SLC1A3	EAAT1	48 μM	K_m (³ H]Glu uptake)	Influx	52		GRM2	mGlu ₂	1.8–26 μM	EC ₅₀ (Ca ²⁺ assay, [³⁵ S]GTPγS)	57,58
SLC1A5	ASC12	3,900–4,800 μM	K_m (³ H]Glu uptake, ΔpH)	Influx / efflux	59		GRM3	mGlu ₃	1 μM	EC ₅₀ (Ca ²⁺ assay)	57
SLC1A6	EAAT4	2.5 μM	K_m (³ H]Glu uptake)	Influx	60		GRM4	mGlu ₄	20–38 μM	EC ₅₀ (CaMP assay)	61,62
SLC1A7	EAAT5	64 μM	E_{50} (EP)	Influx	63		GRM5	mGlu ₅	2.7–4.8 μM	EC ₅₀ (Ca ²⁺ , IP ₃ assay)	64
SLC17A1	XCT	92 μM	K_m (³ H]Glu uptake)	Efflux	65		GRM6	mGlu ₆	6.7–7.6 μM	EC ₅₀ (CaMP assay, [³⁵ S]GTPγS)	58,66
SLC17A5	Sialin	~500 μM	Transported*	Vesicular	67		GRM7	mGlu ₇	56–1000 μM	EC ₅₀ (CaMP assay, [³⁵ S]GTPγS)	58,61
SLC17A6	VGLUT1	~1,000 μM	Transported*	Vesicular	68		GRM8	mGlu ₈	11 μM	EC ₅₀ (CaMP assay)	61
SLC17A7	VGLUT2	~1,000 μM	Transported*	Vesicular	68						
SLC17A8	VGLUT3	~1,000 μM	Transported*	Vesicular	68						
SLC22A7	OAT2	~1,000 μM	Transported*	Vesicular	69						
SLC22A11	OAT4	~1,000 μM	Transported*	Efflux	70,71						
SLC22A13	OAT10	~1,000 μM	Transported*	Efflux	72						
SLC22A14	OAT12	~1,000 μM	Transported*	Efflux	73						
SLC22B1	OATP2B1	~1,000 μM	Transported*	Efflux	71						
SLC6A1	GAT1	11–14 μM	K_m (³ H]GABA uptake, EP)	Influx	73,74		GABA	GABBR1	GABA _A	72 μM	K_i (³ H]ICG54626 binding)
SLC6A6	TauT	2,400 μM	K_m (³ H]GABA uptake)	Influx	76	GABBR2		(dimer)	0.16 μM	EC ₅₀ (Ca ²⁺ assay)	
SLC6A11	GAT3	8.1–172 μM	K_m (³ H]GABA uptake)	Influx	74,77						
SLC6A12	BGT1	~18–20 μM	K_m (³ H]GABA uptake)	Influx	74,78						
SLC6A13	GAT2	8.2 μM	K_m (³ H]GABA uptake)	Influx	79						
SLC32A1	VGAT	~1,000 μM	Transported*	Vesicular	80						
SLC36A1	PAT1	3,100 μM	K_i (³ H]proline inhibition)	Influx	81						
SLC6A10	TAT1	1,212 μM	K_m (³ H]DOPA uptake)	Influx	82	L-DOPA	GPR143	GPR143	9,340 nM	K_i (³ H]L-DOPA binding)	83
SLC1A4	ASC11	68 μM	K_m (³ H]alanine uptake)	Influx / efflux	84		GPRC6A	GPRC6	173 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC1A5	ASC12	29 μM	K_m (³ H]alanine uptake)	Influx / efflux	86		CASR	CaR	~1,000 μM	EC ₅₀ (allosteric modulation of Ca ²⁺)	53,54
SLC6A14	ATB ⁻	99 μM	K_m / EC ₅₀ (EP)	Influx	87	L-alanine					
SLC6A15	B ⁺ AT2	99 μM	Transported*	Influx	88						
SLC6A19	B ⁺ AT1	99 μM	Transported*	Influx	88						
SLC7A8	LAT2	99 μM	Transported*	Influx	89						
SLC7A9	b ⁺ -AT	99 μM	Transported*	Influx	90						
SLC7A10	Asc-1	9.2 μM	Transported*	Influx / efflux	91						
SLC36A1	PAT1	6,000 μM	K_m (¹⁴ C]alanine uptake)	Influx	92						
SLC36A4	PAT4	1,480 μM	K_i (³ H]proline inhibition)	Influx	93						
SLC38A1	SNAT1	1,480 μM	K_i (³ H]proline inhibition)	Influx	94						
SLC38A2	SNAT2	1,480 μM	Transported*	Influx	94						
SLC38A4	SNAT4	1,480 μM	Transported*	Influx	94						
SLC38A5	SNAT5	1,480 μM	Transported*	Influx	94						
SLC38A7	SNAT7	1,480 μM	Transported*	Influx	94						

Solute carrier transporter (SLC)				Substrate		G protein-coupled receptor (GPCR)				
Gene	Protein	Affinity / activity	Comments	Mode of transport	Ref	Gene	Protein	Affinity / potency	Comments	Ref
SLC66A14	ATB ^{0,-}	104 μM	K _m / EC ₅₀ (EP)	Influx	87	GPCR6A	GPCR6	4.4 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC7A1	CAT-1	110-160 μM	K _m (³ H)arginine uptake)	Influx	96					
SLC7A2	CAT-2	320-3,900 μM	K _m (³ H)arginine uptake)	Influx	96					
SLC7A3	CAT-3	450 μM	K _m (³ H)arginine uptake)	Influx	97					
SLC7A6	y ⁺ LAT2	120 μM	K _m (¹⁴ C)arginine uptake)	Influx / efflux	98					
SLC7A7	y ⁺ LAT1		<i>Transported*</i>	Influx / efflux	99					
SLC7A9	b ^{0,-} AT		<i>Transported*</i>	Influx / efflux	91					
SLC38A4	SNAT4		<i>Transported*</i>	Influx / efflux	94					
SLC38A9	SLC38A9	2,700 μM	K _m (³ H)arginine uptake)	Lysosome	100					
SLC7A5	LAT1	790 μM	K _m (¹⁴ C)citrulline uptake)	Influx	101	GPCR6A	GPCR6	287 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC1A5	ASC2	39-1,800 μM	K _m (³ H)glutamine uptake)	Influx / efflux	86	GPCR6A	GPCR6	590 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC66A14	ATB ^{0,-}	633 μM	K _m / EC ₅₀ (EP)	Influx	87	CASR	CaR	~1,000 μM	EC ₅₀ (allosteric modulation of Ca ²⁺)	53,54
SLC66A15	B ⁺ AT2		<i>Transported*</i>	Influx	88					
SLC66A19	B ⁺ AT1		<i>Transported*</i>	Influx	89					
SLC7A5	LAT1	1,640 μM	K _m (¹⁴ C)glutamine uptake)	Influx / efflux	102					
SLC7A6	y ⁺ LAT2	295 μM	K _m (¹⁴ C)glutamine uptake)	Influx	98					
SLC7A8	LAT2		<i>Transported*</i>	Influx	90					
SLC36A4	PAT4	430 μM	K _i (³ H)proline inhibition)	Influx	93					
SLC38A1	SNAT1		<i>Transported*</i>	Influx	94					
SLC38A2	SNAT2		<i>Transported*</i>	Influx	94					
SLC38A3	SNAT3		<i>Transported*</i>	Influx	103					
SLC38A5	SNAT5	1,600 μM	K _m (³ H)glutamine uptake)	Influx	95					
SLC38A7	SNAT7		<i>Transported*</i>	Influx	94					
SLC38A9	SLC38A9	518 μM	K _m (³ H)glutamine uptake)	Lysosome	100					
SLC6A5	GYT2	108 μM	K _m (³ H)glycine uptake)	Influx	104	GPCR6A	GPCR6	263 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC6A9	GYT1	70-90 μM	K _m (³ H)glycine uptake)	Influx / efflux	105					
SLC6A14	ATB ^{0,-}	111 μM	K _m / EC ₅₀ (EP)	Influx	87					
SLC7A10	Asc-1		<i>Transported*</i>	Influx	92					
SLC36A1	PAT1	9,900 μM	K _i (³ H)proline inhibition)	Influx	81					
SLC36A2	PAT2	490 μM	K _m (EP)	Influx	106					
SLC38A1	SNAT1		<i>Transported*</i>	Influx	94					
SLC38A2	SNAT2		<i>Transported*</i>	Influx	94					
SLC38A4	SNAT4		<i>Transported*</i>	Influx	94					
SLC38A5	SNAT5		<i>Transported*</i>	Influx	95					
SLC66A14	ATB ^{0,-}	100 μM	K _m / EC ₅₀ (EP)	Influx	87	GPCR6A	GPCR6	169 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC7A1	CAT-1		<i>Transported*</i>	Influx	107	CASR	CaR	> 10,000 μM	EC ₅₀ (allosteric modulation of Ca ²⁺)	53,54
SLC7A2	CAT-2		<i>Transported*</i>	Influx	107					
SLC7A3	CAT-3		<i>Transported*</i>	Influx	97					
SLC7A6	y ⁺ LAT2	650 μM	K _m (³ H)lysine uptake)	Influx / efflux	98					
SLC7A7	y ⁺ LAT1		<i>Transported*</i>	Influx / efflux	99					
SLC7A9	b ^{0,-} AT		<i>Transported*</i>	Influx / efflux	91					
SLC38A4	SNAT4		<i>Transported*</i>	Influx	94					

Solute carrier transporter (SLC)				Substrate		G protein-coupled receptor (GPCR)				
Gene	Protein	Affinity / activity	Comments	Mode of transport	Ref	Gene	Protein	Affinity / potency	Comments	Ref
SLC6A14	ATB ^{0,-}	1.4 μM	K _m / EC ₅₀ (EP)	Influx	87	GPRC6A	GPRC6	854 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC6A15	B ⁰ AT2	110 μM	K _{0.5} (EP)	Influx	88					
SLC6A19	B ⁰ AT1		<i>Transported*</i>	Influx	89					
SLC7A5	LAT1	20 μM	K _m ([¹⁴ C]methionine uptake)	Influx / efflux	102					
SLC7A9	b ⁰ -AT		<i>Transported*</i>	Influx / efflux	91					
SLC36A4	PAT4	440 μM	K _i ([³ H]proline inhibition)	Influx	93					
SLC38A1	SNAT1		<i>Transported*</i>	Influx	94					
SLC38A2	SNAT2		<i>Transported*</i>	Influx	94					
SLC38A4	SNAT4		<i>Transported*</i>	Influx	94					
SLC43A1	LAT3		<i>Transported*</i>	Influx	108					
SLC43A2	LAT4		<i>Transported*</i>	Influx / efflux	109					
SLC7A1	CAT-1		<i>Transported*</i>	Influx	107	GPRC6A	GPRC6	112 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC7A2	CAT-2		<i>Transported*</i>	Influx	107					
SLC7A3	CAT-3		<i>Transported*</i>	Influx	97					
SLC6A10	TAT1	910 μM	K _m ([¹⁴ C]ornithine uptake)	Influx	82	GPR139	GPR139	60 μM	EC ₅₀ (Ca ²⁺ assay)	110
SLC6A14	ATB ^{0,-}	741 μM	K _m ([¹⁴ C]phenylalanine uptake)	Influx	87	CASR	CaR	1,000–3,500 μM	EC ₅₀ (allosteric modulation of Ca ²⁺)	83,84
SLC6A19	B ⁰ AT1	1.7 μM	K _m / EC ₅₀ (EP)	Influx	87					
SLC7A5	LAT1		<i>Transported*</i>	Influx	89					
SLC7A8	LAT2	1.4 μM	K _m ([¹⁴ C]phenylalanine uptake)	Influx / efflux	102					
SLC7A9	b ⁰ -AT		<i>Transported*</i>	Influx	90					
SLC43A1	LAT3	6.5–1,206 μM	K _m ([¹⁴ C]phenylalanine uptake)	Influx / efflux	91					
SLC43A2	LAT4	178–3,733 μM	K _m ([³ H]phenylalanine uptake)	Influx / efflux	108					
SLC6A10	TAT1		<i>Transported*</i>	Influx	82	GPR139	GPR139	49 μM	EC ₅₀ (Ca ²⁺ assay)	110
SLC6A14	ATB ^{0,-}	452 μM	K _m ([¹⁴ C]tryptophan uptake)	Influx	87	CASR	CaR	30–100 μM	EC ₅₀ (allosteric modulation of Ca ²⁺)	83,84
SLC7A5	LAT1	26 μM	K _m / EC ₅₀ (EP)	Influx / efflux	102					
SLC7A8	LAT2	21 μM	K _m ([¹⁴ C]tryptophan uptake)	Influx	90					
SLC36A4	PAT4	1.7 μM	K _i ([³ H]proline inhibition)	Influx	93					
SLC1A4	ASCT1	121 μM	K _m ([³ H]serine uptake)	Influx	84	GPRC6A	GPRC6	623 μM	EC ₅₀ (Ca ²⁺ assay)	85
SLC1A5	ASCT2	56–6,600 μM	K _m ([³ H]serine uptake)	Influx / efflux	86	CASR	CaR	~1,000 μM	EC ₅₀ (allosteric modulation of Ca ²⁺)	83,84
SLC6A14	ATB ^{0,-}	43 μM	K _m / EC ₅₀ (EP)	Influx	87					
SLC6A15	B ⁰ AT2		<i>Transported*</i>	Influx	88					
SLC6A19	B ⁰ AT1		<i>Transported*</i>	Influx	89					
SLC7A10	Asc-1		<i>Transported*</i>	Influx	92					
SLC38A1	SNAT1		<i>Transported*</i>	Influx	94					
SLC38A2	SNAT2		<i>Transported*</i>	Influx	94					
SLC38A4	SNAT4		<i>Transported*</i>	Influx	94					
SLC38A5	SNAT5		<i>Transported*</i>	Influx	95					
SLC38A7	SNAT7		<i>Transported*</i>	Influx	94					

Solute carrier transporter (SLC)				Substrate				G protein-coupled receptor (GPCR)			
Gene	Protein	Affinity / activity	Comments	Mode of transport	Ref	Gene	Protein	Affinity / potency	Comments	Ref	
Prostaglandins											
SLC02A1	PGT	83 nM	$K_{1/2}$ (^3H] PGE_2 inhibition)	Influx / efflux	111						
SLC02A1	PGT	82 nM	$K_{1/2}$ (^3H] PGE_2 inhibition)	Influx / efflux	111		DP ₁	1.7 nM	K (^3H] PGD_2 binding)	112	
SLC03A1	OATP3A1	49 nM	K_m (^3H] PGE_1 uptake)	Influx / efflux	114		EP ₁	5,820 nM	K (^3H] PGE_2 binding)	112	
							EP ₂	2,973 nM	K (^3H] PGE_2 binding)	112	
							EP ₃	421 nM	K (^3H] PGE_2 binding)	112	
							EP ₄	1,483 nM	K (^3H] PGE_2 binding)	112	
							PTGFR	6.7 nM	K (^3H] PGE_2 binding)	112	
							TBXA2R	6,602 nM	K (^3H] SQ-29548 binding)	112	
SLC02A1	PGT	82 nM	$K_{1/2}$ (^3H] PGE_2 inhibition)	Influx / efflux	111		DP ₁	53 nM	K (^3H] PGD_2 binding)	113	
SLC03A1	OATP3A1	49 nM	K_m (^3H] PGE_1 uptake)	Influx / efflux	114		EP ₁	165 nM	K (^3H] PGE_2 binding)	116	
							EP ₂	1 nM	IC_{50} (^3H] PGE_2 binding)	116	
							EP ₃	1.5 nM	K (^3H] PGE_2 binding)	117	
							EP ₄	318 nM	K (^3H] loprost binding)	118	
SLC02A1	PGT	100–331 nM	$K_{1/2}$ (^3H] PGE_2 inhibition)	Influx / efflux	111,119		DP ₁	307 nM	K (^3H] PGD_2 binding)	112	
SLC03A1	OATP3A1	56 nM	K_m (^3H] PGE_2 uptake)	Influx / efflux	114		EP ₁	9.1 nM	K (^3H] PGE_2 binding)	112	
SLC22A1	OCT1	657 nM #	K_m (^3H] PGE_2 uptake)	Influx	120		EP ₂	4.9 nM	K (^3H] PGE_2 binding)	112	
SLC22A1	OCT2	29 nM #	K_m (^3H] PGE_2 uptake)	Influx	120		EP ₃	0.3 nM	K (^3H] PGE_2 binding)	112	
SLC22A6	OAT1	970 nM	K_m (^3H] PGE_2 uptake)	Influx	120		EP ₄	0.8 nM	K (^3H] PGE_2 binding)	112	
SLC22A7	OAT2	713 nM	K_m (^3H] PGE_2 uptake)	Influx	120		PTGFR	119 nM	K (^3H] PGE_2 binding)	112	
SLC22A8	OAT3	345 nM	K_m (^3H] PGE_2 uptake)	Influx	120		TBXA2R	29,000 nM	K (^3H] SQ-29548 binding)	112	
SLC22A11	OAT4	154 nM	K_m (^3H] PGE_2 uptake)	Influx	120						
SLC02A1	PGT	7,202 nM	$K_{1/2}$ (^3H] PGE_2 inhibition)	Influx / efflux	119		EP ₁	110 nM	IC_{50} (^3H] PGE_2 binding)	121	
							EP ₂	20 nM	IC_{50} (^3H] PGE_2 binding)	121	
							EP ₃	37 nM	IC_{50} (^3H] PGE_2 binding)	121	
							EP ₄	17 nM	IC_{50} (^3H] PGE_2 binding)	121	
SLC02A1	PGT	92 nM	$K_{1/2}$ (^3H] PGE_2 inhibition)	Influx / efflux	111		DP ₁	861 nM	K (^3H] PGD_2 binding)	112	
SLC16A5	MCT6	477 nM #	K_m (^3H] PGE_2 uptake)	Influx	122		EP ₁	964 nM	K (^3H] PGE_2 binding)	112	
SLC22A1	OCT1	334 nM #	K_m (^3H] PGE_2 uptake)	Influx	120		EP ₂	38 nM	K (^3H] PGE_2 binding)	112	
SLC22A1	OCT2	575 nM	K_m (^3H] PGE_2 uptake)	Influx	120		EP ₃	288 nM	K (^3H] PGE_2 binding)	112	
SLC22A6	OAT1	1,092 nM	K_m (^3H] PGE_2 uptake)	Influx	120		EP ₄	3.2 nM	K (^3H] PGE_2 binding)	112	
SLC22A8	OAT3	692 nM	K_m (^3H] PGE_2 uptake)	Influx	120		PTGFR				
SLC22A11	OAT4			Influx	120		TBXA2R	8,700 nM	K (^3H] SQ-29548 binding)	112	

Solute carrier transporter (SLC)				G protein-coupled receptor (GPCR)							
Gene	Protein	Affinity / activity	Comments	Mode of transport	Ref	Substrate	Gene	Protein	Affinity / potency	Comments	Ref
Monocarboxylates & short-chain fatty acids											
SLC5A8	SMCT1	159–252 μM	K_m (^{14}C)lactate uptake, (EP)	Influx	123	Lactate	HCAR1	HCA ₁	1,500–7,000 μM	EC_{50} (^{35}S IGTPyS, Ca^{2+} assay)	124
SLC5A12	SMCT2	16,900 μM	IC_{50} (^{14}C)nicotinate inhibition)	Influx	126						
SLC16A1	MCT1	4,500–6,000 μM	K_m (^{14}C)lactate uptake)	Influx / efflux	126						
SLC16A3	MCT4	700–37,600 μM	K_m (pH sensor)	Influx / efflux	126						
SLC16A7	MCT2	6,500 μM	K_m (^{14}C)lactate uptake)	Influx	126						
SLC16A8	MCT3		<i>Transported*</i>	Influx / efflux	126						
SLC5A8	SMCT1	230 μM	$K_{0.5}$ (EP)	Influx	127						
SLC5A12	SMCT2	3,700 μM	IC_{50} (^{14}C)nicotinate inhibition)	Influx	126						
SLC22A7	OAT2	17 μM	K_m (^3H)nicotinate uptake)	Influx	130	Nicotinate	HCAR2	HCA ₂	0.1–0.25 μM	EC_{50} (^{35}S IGTPyS)	128,129
SLC22A9	OAT7		<i>Transported*</i>	Influx	131		HCAR3	HCA ₃	~ 1,000 μM	EC_{50} (^{35}S IGTPyS)	128,129
SLC22A13	OAT10	22–48 μM	K_m (^3H)nicotinate uptake)	Influx	132	Butyrate	FFAR3	FFA ₃	158 μM	EC_{50} (^{35}S IGTPyS)	133
SLC5A8	SMCT1	72 μM	K_m (EP)	Influx	123		FFAR2	FFA ₂	371 μM	EC_{50} (^{35}S IGTPyS)	133
SLC5A12	SMCT2	2,600 μM	IC_{50} (^{14}C)nicotinate inhibition)	Influx	126		HCAR2	HCA ₂	1,590 μM	EC_{50} (^{35}S IGTPyS)	129
SLC16A1	MCT1	9,000–10,000 μM	K_m (^{14}C)butyrate uptake)	Influx	128		FFAR3	FFA ₃	1,020 μM	EC_{50} (^{35}S IGTPyS)	133
SLC22A9	OAT7	36 μM	K_m (^{14}C)butyrate uptake)	Influx / efflux	131	FFAR2	FFA ₂	431 μM	EC_{50} (^{35}S IGTPyS)	133	
SLC5A8	SMCT1	2,460 μM	$K_{0.5}$ (EP)	Influx	134	FFAR3	FFA ₃	127 μM	EC_{50} (^{35}S IGTPyS)	133	
SLC5A8	SMCT1	128 μM	K_m (EP)	Influx	123	FFAR2	FFA ₂	290 μM	EC_{50} (^{35}S IGTPyS)	133	
SLC5A8	SMCT1	1,442 μM	K_m (EP)	Influx	135	β -D-hydroxybutyrate	HCAR2	HCA ₂	767 μM	EC_{50} (^{35}S IGTPyS)	129
SLC16A1	MCT1	10,000 μM	K_m (pH sensor)	Influx	126		HCAR3	HCA ₃	> 25,000 μM	EC_{50} (^{35}S IGTPyS)	129
SLC16A3	MCT4	130,000 μM	K_m (pH sensor)	Influx	126						
SLC16A7	MCT2		<i>Transported*</i>	Influx	126						

Solute carrier transporter (SLC)				G protein-coupled receptor (GPCR)							
Gene	Protein	Affinity / activity	Comments	Mode of transport	Ref	Substrate	Gene	Protein	Affinity / potency	Comments	Ref
Other carboxylic acids & signaling lipids											
SLC13A2	NaDC1	590–800 μM	K_m (^{14}C)succinate uptake)	Influx	136	Succinate	SUCNR1	SUCNR1	28–56 μM	EC_{50} (Ca^{2+} assay)	137
SLC13A3	NaDC3	2–25 μM	K_m (^3H)succinate uptake, EP)	Influx	136						
SLC13A5	NaDC2	1,920 μM	IC_{50} (^{14}C)citrate inhibition)	Influx	138–140						
SLC16A1	MCT1		Transported*	Efflux	141						
SLC22A6	OAT1	4,825 μM	IC_{50} (^3H)PAH inhibition)	Influx	141						
SLC22A8	OAT3	55,700 μM	IC_{50} (^3H)estron sulfate inhibition)	Influx	141						
SLC59A1	MFSDA		Transported (SPNS2 complex)	Influx / efflux	142	Sphingosine-1-phosphate	S1PR1	S1P ₁	0.9–1.2 nM	EC_{50} (^{35}S)GTP γS)	143,144
SLC59A2	MFSDB		Transported*	Efflux	145		S1PR2	S1P ₂	2.9–8.9 nM	EC_{50} (^{35}S)GTP γS)	143,144
SLC63A2	SPNS2		Transported*	Efflux	146		S1PR3	S1P ₃	0.2–1.1 nM	EC_{50} (^{35}S)GTP γS)	144
							S1PR4	S1P ₄	8.6 nM	EC_{50} (^{35}S)GTP γS)	143,144
							S1PR5	S1P ₅	11–44 nM	EC_{50} (^{35}S)GTP γS)	147
							GPR3	GPR3	50 nM [#]	EC_{50} (Ca^{2+} assay)	147
							GPR6	GPR6	56 nM [#]	EC_{50} (Ca^{2+} assay)	147
							GPR12	GPR12	106 nM [#]	EC_{50} (Ca^{2+} assay)	147
							GPR63	GPR63	800 nM [#]	EC_{50} (Ca^{2+} assay)	148
							P2RY10	P2Y ₁₀	53 nM	EC_{50} (Ca^{2+} assay)	149
SLC10A1	NTCP	6.3 μM	K_m (^3H)taurocholate uptake)	Influx	150	Bile acids	GPBAR1	GPBAR	0.3–7.7 μM	EC_{50} (cAMP assay)	151
SLC10A2	ASBT	4.1–33 μM	K_m (^3H)bile acid uptake)	Influx	152		S1PR2	S1P ₂		Activation*	153
SLC22A24	SLC22A24		Transported*	Influx / efflux	154						
SLC51A/B	OST α / β	13–1,000 μM	K_m (LC-MS/MS)	Influx / efflux	155						
SLC01A2	OATP1A2	19–60 μM	K_m (^3H)bile acid uptake)	Influx	156						
SLC01B1	OATP1B1	0.7–47 μM	K_m (LC-MS/MS)	Influx	157						
SLC01B3	OATP1B3	0.5–42 μM	K_m (LC-MS/MS)	Influx	157						
SLC03A1	OATP3A1		Transported*	Influx / efflux	158						
SLC27A1	FAIP1		K_m (^{14}C)oleic acid uptake)	Influx / efflux	159,160	(Very) long-chain fatty acids	FFAR1	FFA1	1–43 μM	EC_{50} (Ca^{2+} assay)	161,162
SLC27A2	FAIP2	0.2 μM	Transported*	Influx / efflux	163		FFAR2	FFA4	12–63 μM	EC_{50} (Ca^{2+} , DMR, β -arrestin)	164
SLC27A4	FAIP4		Transported*	Influx / efflux	159,165						
SLC27A6	FAIP6		Transported*	Influx / efflux	159						

* no affinity or potency values reported for human orthologues, but evidence for binding or transport
 # disputed results

Yellow fill indicates SLC-GPCR pair that has been subject to in-house TRACT assay attempts
 Blue fill indicates SLC-GPCR pair for which TRACT assays are published or reported in this thesis

Table A.2 – List of Na⁺-coupled transporters that are expressed at the plasma membrane. Transport stoichiometries were derived from the IUPHAR Guide to Pharmacology¹⁶⁶. Only transporters for which stoichiometries were described are mentioned in this table; putative and orphan transporters are not included here.

Gene	Protein	Stoichiometry
Na⁺-coupled transporters at the plasma membrane		
SLC1A1/2/3/6/7	EAAT3/2/1/4/5	3 Na ⁺ / 1 glu ⁻ / 1 H ⁺ in : 1 K ⁺ out (Cl ⁻ conductivity)
SLC1A4/5	ASCT1/2	1 Na ⁺ / 1 amino acid in : 1 Na ⁺ / 1 amino acid out
SLC4A4/5	NBCe1/2	1 Na ⁺ / 2-3 HCO ₃ ⁻ or 1 CO ₃ ²⁻ in/out
SLC4A7/10	NBCn1/2	1 Na ⁺ / 1 HCO ₃ ⁻ or 1 CO ₃ ²⁻ in/out
SLC4A8	NDCBE	1 Na ⁺ / 2 HCO ₃ ⁻ / 1 Cl ⁻ in/out
SLC5A1/2	SGLT1/2	1-2 Na ⁺ / 1 glucose in
SLC5A3/11	SMIT1/2	2 Na ⁺ / 1 myo-inositol in
SLC5A5	NIS	2 Na ⁺ / 1 I ⁻ in
SLC5A6	SMVT	2 Na ⁺ / 1 biotin in
SLC5A7	CHT	1 Na ⁺ / 1 choline in
SLC5A8/12	SMCT1/2	2 Na ⁺ / 1 monocarboxylate ⁻ in
SLC6A1/11/13/12	GAT1/2/3/BGT1	2-3 Na ⁺ / 1-2 Cl ⁻ / 1 GABA in
SLC6A2	NET	1 Na ⁺ / 1 Cl ⁻ / 1 NE in
SLC6A3	DAT	1-2 Na ⁺ / 1 Cl ⁻ / 1 DA in
SLC6A4	SERT	1 Na ⁺ / 1 Cl ⁻ / 1 5-HT in : 1 K ⁺ out
SLC6A5/9	GlyT1/2	2-3 Na ⁺ / 1 Cl ⁻ / 1 glycine in
SLC6A6	TauT	2 Na ⁺ / 1 Cl ⁻ / 1 taurine in
SLC6A7	PROT	2 Na ⁺ / 1 Cl ⁻ / 1 L-proline in
SLC6A8	CT1	2 Na ⁺ / 1 Cl ⁻ / 1 creatine in
SLC6A14/20	ATB ^{0,+} /SIT1	2-3 Na ⁺ / 1 Cl ⁻ / 1 amino acid in
SLC6A19/15	B ⁰ AT1/2	1 Na ⁺ / 1 amino acid in
SLC8A1	NCX1	3-4 Na ⁺ in : 1 Ca ²⁺ out (or 1 Ca ²⁺ in : 1 Na ⁺ out)
SLC9 family	NHE	1 Na ⁺ in : 1 H ⁺ out
SLC10A1/2	NTCP/ASBT	1-2 Na ⁺ / 1 bile acid in
SLC12A2/1	NKCC1/2	1 Na ⁺ / 1 K ⁺ / 2 Cl ⁻ in
SLC12A3	NCC	1 Na ⁺ / 1 Cl ⁻ in
SLC13A1/4	NaS1/2	3 Na ⁺ / SO ₄ ²⁻ in
SLC13A2	NaDC1	3 Na ⁺ / 1 dicarboxylate ²⁻ in
SLC20A1/2	PI1/2	1 Na ⁺ / 1 HPO ₄ ²⁻ in
SLC23A1/2	SVCT1/2	2 Na ⁺ / 1 ascorbic acid in
SLC24A1-5	NKCX1-5	4 Na ⁺ in : 1 Ca ²⁺ / 1 K ⁺ out
SLC28A1-3	CNT1-3	1 Na ⁺ / 1 nucleoside
SLC34A1/2/3	NaPi-2a/b/c	3 Na ⁺ / 1 HPO ₄ ²⁻ in
SLC38A1/2/4	SNAT1/2/4	1 Na ⁺ / 1 amino acid in
SLC38A3/5	SNAT3/5	1 Na ⁺ / 1 amino acid in : 1 H ⁺ out

Abbreviations

5-CT	5-carboxamidotryptamine	L-DOPA	L-3,4-dihydroxyphenylalanine (levodopa)
5-HT	5-hydroxytryptamine (serotonin)	LSD	lysergic acid diethylamide
5-HT _x	serotonin receptor	M _x	muscarinic acetylcholine receptor
α_x / β_x	alpha / beta adrenergic receptor	MCT	monocarboxylate transporter
A _x	adenosine receptor	mGlu _x	metabotropic glutamate receptor
ACh	acetylcholine	mito	mitochondria
ADE	adenosine	MPP+	1-methyl-4-phenylpyridinium
ADP	adenosine diphosphate	MT _x	melatonin receptor
AGT	aspartate/glutamate transporter	NaDC	Na ⁺ /dicarboxylate cotransporter
ASBT	apical Na ⁺ /bile acid transporter	NaPi-2	Na ⁺ /phosphate cotransporter
ASCT	alanine/serine/cysteine transporter	NaS	Na ⁺ /sulfate cotransporter
Asc	Asc-type amino acid transporter	N(K)CC	Na ⁺ (/K ⁺)/Cl ⁻ cotransporter
ATB ⁰⁺	B ⁰⁺ -type amino acid transporter	N(K)CX	Na ⁺ (/K ⁺)/Cl ⁻ exchanger
ATP	adenosine triphosphate	NBCe	electrogenic Na ⁺ /bicarbonate transporter
b ⁰⁺ AT	b ⁰⁺ -type amino acid transporter	NBCn	neutral Na ⁺ /bicarbonate transporter
B ⁰ AT	B ⁰ -type amino acid transporter	NDCBE	neutral Na ⁺ /bicarbonate/Cl ⁻ transporter
BGT	betaine/GABA transporter	NE	norepinephrine
cAMP	cyclic adenosine monophosphate	NET	norepinephrine transporter
CaR	calcium-sensing receptor	NHE	Na ⁺ /proton exchanger
CAT	cationic amino acid transporter	NIS	Na ⁺ /iodide cotransporter
CHT	choline transporter	NMS	N-methylscopolamine
CNT	concentrative nucleoside transporter	NTCP	Na ⁺ /bile acid cotransporter
CT1	creatine transporter 1	OAT	organic anion transporter
CYP	cyanopindolol	OATP	organic anion-transporting polypeptides
D _x	dopamine receptor	OCT	organic cation transporter
DA	dopamine	OCTN1	ergothioneine transporter
DAT	dopamine transporter	OST α/β	organic solute transporter α/β
DMR	dynamic mass redistribution	P2Y	purinergic P2Y receptor
DP ₁	prostaglandin D ₂ receptor	PAT	proton-coupled amino acid transporter
EAAT	excitatory amino acid transporter	PAH	para-aminohippurate
EC ₅₀	half maximal effective concentration	PEPT	peptide transporter
EP	electrophysiology	PGD ₂	prostaglandin D ₂
EP _x	prostaglandin E ₁₋₄ receptor	PGE _x	prostaglandin E ₁₋₃
EPI	epinephrine	PGF _{2α}	prostaglandin F _{2α}
ENT	equilibrative nucleoside transporter	PGT	prostaglandin transporter
FATP	fatty acid transport protein	PI ^T	Na ⁺ -dependent phosphate transporter
FFAR	free fatty acid receptor	PMAT	plasma membrane monoamine transporter
FP	prostaglandin F _{2α} receptor	PROT	proline transporter
GABA	gamma-aminobutyric acid	SIP _x	sphingosine-1-phosphate receptor
GABA _B	metabotropic GABA receptor	SERT	serotonin transporter
GAT	GABA transporter	SGLT	Na ⁺ /glucose cotransporter
Glu	glutamate	SIT	Na ⁺ /imino acid transporter
GLUT	glucose transporter	SLC	solute carrier transporter
GlyT	glycine transporter	SMCT	Na ⁺ -coupled monocarboxylate transporter
GPBAR	G protein-coupled bile acid receptor	SMIT	Na ⁺ /myo-inositol cotransporter
GPR	orphan G protein-coupled receptor	SMVT	Na ⁺ /multivitamin transporter
GPCR	G protein-coupled receptor	SNAT	Na ⁺ -coupled neutral amino acid transporter
GTP	guanosine triphosphate	SPNS	Spinster homolog/sphingolipid transporter
H _x	histamine receptor	SUCNR	succinate receptor
HCA _x	hydroxycarboxylic acid receptor	SVCT	Na ⁺ /vitamin C transporter
HIS	histamine	TA ₁	trace amine-associated receptor 1
IC ₅₀	half maximal inhibitory concentration	TAT	T-type amino acid transporter
IP	prostaglandin I ₂ receptor	TauT	taurine transporter
IP ₃	inositol triphosphate	TEA	tetraethylammonium
K _{0.5} / K _{1/2}	apparent affinity constant	TP	thromboxane receptor
K _d	dissociation constant	VACHT	vesicular acetylcholine transporter
K _i	inhibition constant	VGAT	vesicular GABA transporter
K _m	Michaelis-Menten constant	VGLUT	vesicular glutamate transporter
LAT	L-type amino acid transporter	VMAT	vesicular monoamine transporter
LC-MS	liquid chromatography–mass spectrometry	VNUT	vesicular nucleoside transporter
		y ⁺ LAT	y ⁺ L-type amino acid transporter
		xCT	cystine/glutamate transporter

References

1. Pastor-Anglada, M. & Pérez-Torras, S. (2018) Who is who in Adenosine transport. *Front. Pharmacol.* **9**, 627.
2. Yan, L., Burbiel, J. C., Maaß, A. & Müller, C. E. (2003) Adenosine receptor agonists: From basic medicinal chemistry to clinical development. *Expert Opin. Emerg. Drugs* **8**, 537–576.
3. Sawada, K. *et al.* (2008) Identification of a vesicular nucleotide transporter. *Proc. Natl. Acad. Sci. U. S. A.* **105**, 5683–5686.
4. Waldo, G. L. & Harden, T. K. (2004) Agonist binding and Gq-stimulating activities of the purified human P2Y1 receptor. *Mol. Pharmacol.* **65**, 426–436.
5. Lazarowski, E. R., Watt, W. C., Stutts, M. J., Boucher, R. C. & Harden, T. K. (1995) Pharmacological selectivity of the cloned human P2U-purinoceptor: potent activation by diadenosine tetraphosphate. *Br. J. Pharmacol.* **116**, 1619–1627.
6. Communi, D., Govaerts, C., Parmentier, M. & Boeynaems, J. M. (1997) Cloning of a human purinergic P2Y receptor coupled to phospholipase C and adenyllyl cyclase. *J. Biol. Chem.* **272**, 31969–31973.
7. Takasaki, J. *et al.* (2001) Molecular cloning of the platelet P2TAC ADP receptor: Pharmacological comparison with another ADP receptor, the P2Y1 receptor. *Mol. Pharmacol.* **60**, 432–439.
8. Marteau, F. *et al.* (2003) Pharmacological characterization of the human P2Y13 receptor. *Mol. Pharmacol.* **64**, 104–112.
9. Buccioni, M. *et al.* (2011) Innovative functional cAMP assay for studying G protein-coupled receptors: Application to the pharmacological characterization of GPR17. *Purinergic Signal.* **7**, 463–468.
10. Kennedy, C., Qi, A. D., Herold, C. L., Harden, T. K. & Nicholas, R. A. (2000) ATP, an agonist at the rat P2Y4 receptor, is an antagonist at the human P2Y4. *Mol. Pharmacol.* **57**, 926–931.
11. Varoqui, H. & Erickson, J. D. (1996) Active transport of acetylcholine by the human vesicular acetylcholine transporter. *J. Biol. Chem.* **271**, 27229–27232.
12. Jakubík, J., Bačáková, L., El-Fakahany, E. E. & Tuček, S. (1997) Positive cooperativity of acetylcholine and other agonists with allosteric ligands on muscarinic acetylcholine receptors. *Mol. Pharmacol.* **52**, 172–179.
13. Koepsell, H. (2020) Organic cation transporters in health and disease. *Pharmacol. Rev.* **72**, 253–319.
14. Cheng, K. *et al.* (2002) Lithocholylcholine, a bile acid/acetylcholine hybrid, is a muscarinic receptor antagonist. *J. Pharmacol. Exp. Ther.* **303**, 29–35.
15. Apparsundaram, S., Moore, K. R., Malone, M. D., Hartzell, H. C. & Blakely, R. D. (1997) Molecular cloning and characterization of an l-pinephrine transporter from sympathetic ganglia of the bullfrog, *Rana catesbiana*. *J. Neurosci.* **17**, 2691–2702.
16. Giros, B. *et al.* (1994) Delineation of discrete domains for substrate, cocaine, and tricyclic antidepressant interactions using chimeric dopamine-norepinephrine transporters. *J. Biol. Chem.* **269**, 15985–15988.
17. Raffel, D. M. *et al.* (2013) Radiotracers for cardiac sympathetic innervation: transport kinetics and binding affinities for the human norepinephrine transporter. *Nucl. Med. Biol.* **40**, 331–337.
18. Alachkar, A., Brotchie, J. M. & Jones, O. T. (2010) Binding of dopamine and 3-methoxytyramine as l-DOPA metabolites to human α 2-adrenergic and dopaminergic receptors. *Neurosci. Res.* **67**, 245–249.
19. Giros, B. *et al.* (1992) Cloning, pharmacological characterization, and chromosome assignment of the human dopamine transporter. *Mol. Pharmacol.* **42**, 383–390.
20. Erickson, J. D., Schäfer, M. K. H., Bonner, T. I., Eiden, L. E. & Weihe, E. (1996) Distinct pharmacological properties and distribution in neurons and endocrine cells of two isoforms of the human vesicular monoamine transporter. *Proc. Natl. Acad. Sci. U. S. A.* **93**, 5166–5171.
21. Sunahara, R. K. *et al.* (1991) Cloning of the gene for a human dopamine D5 receptor with higher affinity for dopamine than D1. *Nature* **350**, 614–619.
22. Freedman, S. B. *et al.* (1994) Expression and pharmacological characterization of the human D3 dopamine receptor. *J. Pharmacol. Exp. Ther.* **268**, 417–426.
23. Van Tol, H. H. M. *et al.* (1991) Cloning of the gene for a human dopamine D4 receptor with high affinity for the antipsychotic clozapine. *Nature* **350**, 610–614.
24. Lanau, F., Zenner, M. T., Civelli, O. & Hartman, D. S. (1997) Epinephrine and norepinephrine act as potent agonists at the recombinant human dopamine D4 receptor. *J. Neurochem.* **68**, 804–812.
25. Duan, H. & Wang, J. (2010) Selective transport of monoamine neurotransmitters by human plasma membrane monoamine transporter and organic cation transporter 3. *J. Pharmacol. Exp. Ther.* **335**, 743–753.
26. Engel, K. & Wang, J. (2005) Interaction of organic cations with a newly identified plasma membrane monoamine transporter. *Mol. Pharmacol.* **68**, 1397–1407.
27. Borowsky, B. *et al.* (2001) Trace amines: Identification of a family of mammalian G protein-coupled receptors. *Proc. Natl. Acad. Sci.* **98**, 8966–8971.

28. Horie, K., Obika, K., Foglar, R. & Tsujimoto, G. (1995) Selectivity of the imidazoline α -adrenoceptor agonists (oxymetazoline and cirazoline) for human cloned α 1-adrenoceptor subtypes. *Br. J. Pharmacol.* **116**, 1611–1618.
29. Jasper, J. R. *et al.* (1998) Ligand efficacy and potency at recombinant α 2 adrenergic receptors. *Biochem. Pharmacol.* **55**, 1035–1043.
30. Hoffmann, C., Leitz, M. R., Oberdorf-Maass, S., Lohse, M. J. & Klotz, K.-N. (2004) Comparative pharmacology of human β -adrenergic receptor subtypes - characterization of stably transfected receptors in CHO cells. *Naunyn. Schmiedeberg. Arch. Pharmacol.* **369**, 151–159.
31. Pacholczyk, T., Blakely, R. D. & Amara, S. G. (1991) Expression cloning of a cocaine- and antidepressant-sensitive human noradrenaline transporter. *Nature* **350**, 350–354.
32. Ramamoorthy, S. *et al.* (1993) Antidepressant- and cocaine-sensitive human serotonin transporter: molecular cloning, expression, and chromosomal localization. *Proc. Natl. Acad. Sci.* **90**, 2542–2546.
33. Kalipatnapu, S., Pucadyil, T. J., Harikumar, K. G. & Chattopadhyay, A. (2004) Ligand binding characteristics of the human serotonin 1A receptor heterologously expressed in CHO cells. *Biosci. Rep.* **24**, 101–115.
34. Weinschenk, R. L., Zgombick, J. M., Macchi, M. J., Branchek, T. A. & Hartig, P. R. (1992) Human serotonin 1D receptor is encoded by a subfamily of two distinct genes: 5-HT(1D α) and 5-HT(1D β). *Proc. Natl. Acad. Sci. U. S. A.* **89**, 3630–3634.
35. McAllister, G. *et al.* (1992) Molecular cloning of a serotonin receptor from human brain (5HT1E): A fifth 5HT1-like subtype. *Proc. Natl. Acad. Sci. U. S. A.* **89**, 5517–5521.
36. Adham, N. *et al.* (1993) Cloning of another human serotonin receptor (5-HT(1F)): A fifth 5-HT1 receptor subtype coupled to the inhibition of adenylate cyclase. *Proc. Natl. Acad. Sci. U. S. A.* **90**, 408–412.
37. Knight, A. R. *et al.* (2004) Pharmacological characterisation of the agonist radioligand binding site of 5-HT2A, 5-HT2B and 5-HT2C receptors. *Naunyn. Schmiedeberg. Arch. Pharmacol.* **370**, 114–123.
38. Blondel, O., Gastineau, M., Dahmoune, Y., Langlois, M. & Fischmeister, R. (1998) Cloning, expression, and pharmacology of four human 5-hydroxytryptamine4 receptor isoforms produced by alternative splicing in the carboxyl terminus. *J. Neurochem.* **70**, 2252–2261.
39. Rees, S. *et al.* (1994) Cloning and characterisation of the human 5-HT5A serotonin receptor. *FEBS Lett.* **355**, 242–246.
40. Kohen, R. *et al.* (1996) Cloning, characterization, and chromosomal localization of a human 5-HT6 serotonin receptor. *J. Neurochem.* **66**, 47–56.
41. Bard, J. A. *et al.* (1993) Cloning of a novel human serotonin receptor (5-HT7) positively linked to adenylate cyclase. *J. Biol. Chem.* **268**, 23422–23426.
42. Moguilevsky, N. *et al.* (1994) Stable expression of human H1-histamine-receptor cDNA in Chinese hamster ovary cells: Pharmacological characterisation of the protein, tissue distribution of messenger RNA and chromosomal localisation of the gene. *Eur. J. Biochem.* **224**, 489–496.
43. Tahara, A. *et al.* (1998) Pharmacological characterization of the human vasopressin receptor subtypes stably expressed in Chinese hamster ovary cells. *Br. J. Pharmacol.* **125**, 1463–1470.
44. Lovenberg, T. W., Pyati, J., Chang, H., Wilson, S. J. & Erlander, M. G. (2000) Cloning of rat histamine H3 receptor reveals distinct species pharmacological profiles. *J. Pharmacol. Exp. Ther.* **293**, 771–778.
45. Liu, C. *et al.* (2001) Cloning and pharmacological characterization of a fourth histamine receptor (H4) expressed in bone marrow. *Mol. Pharmacol.* **59**, 420–426.
46. Hevia, D. *et al.* (2015) Melatonin uptake through glucose transporters: A new target for melatonin inhibition of cancer. *J. Pineal Res.* **58**, 234–250.
47. Audinot, V. *et al.* (2003) New selective ligands of human cloned melatonin MT1 and MT2 receptors. *Naunyn. Schmiedeberg. Arch. Pharmacol.* **367**, 553–561.
48. Huo, X. *et al.* (2017) Human transporters, PEPT1/2, facilitate melatonin transportation into mitochondria of cancer cells: An implication of the therapeutic potential. *J. Pineal Res.* **62**, 1–18.
49. Sitte, H. H. *et al.* (1998) Carrier-mediated release, transport rates, and charge transfer induced by amphetamine, tyramine, and dopamine in mammalian cells transfected with the human dopamine transporter. *J. Neurochem.* **71**, 1289–1297.
50. Hilber, B. *et al.* (2005) Serotonin-transporter mediated efflux: A pharmacological analysis of amphetamines and non-amphetamines. *Neuropharmacology* **49**, 811–819.
51. Sarkar, S. & Berry, M. D. (2020) Involvement of organic cation transporter 2 and a Na⁺-dependent active transporter in p-tyramine transport across Caco-2 intestinal cells. *Life Sci.* **253**, 117696.
52. Arriza, J. *et al.* (1994) Functional comparisons of three glutamate transporter subtypes cloned from human motor cortex. *J. Neurosci.* **14**, 5559–5569.
53. Conigrave, A. D., Quinn, S. J. & Brown, E. M. (2000) L-Amino acid sensing by the extracellular Ca²⁺-sensing receptor. *Proc. Natl. Acad. Sci.* **97**, 4814–4819.
54. Liu, H. *et al.* (2020) Illuminating the allosteric modulation of the calcium-sensing receptor. *Proc. Natl. Acad. Sci. U. S. A.* **117**, 21711–21722.

55. Desai, M. A., Burnett, J. P., Mayne, N. G. & Schoepp, D. D. (1995) Cloning and expression of a human metabotropic glutamate receptor 1 α : Enhanced coupling on co-transfection with a glutamate transporter. *Mol. Pharmacol.* **48**, 648–657.
56. Lin, F. F. *et al.* (1997) Cloning and stable expression of the mGluR1b subtype of human metabotropic receptors and pharmacological comparison with the mGluR5a subtype. *Neuropharmacology* **36**, 917–931.
57. Monn, J. A. *et al.* (2015) Synthesis and pharmacological characterization of C4-(thio-triazolyl)-substituted-2-aminobicyclo[3.1.0]hexane-2,6-dicarboxylates. Identification of (1R,2S,4R,5R,6R)-2-amino-4-(1H-1,2,4-triazol-3-ylsulfanyl)bicyclo[3.1.0]hexane-2,6-dicarboxylic acid (LY2812). *J. Med. Chem.* **58**, 7526–7548.
58. Filosa, R. *et al.* (2006) Synthesis and biological evaluation of (2S)- and (2R)-2-(3'-phosphonobicyclo[1.1.1]pentyl)glycines as novel group III selective metabotropic glutamate receptor ligands. *Bioorganic Med. Chem.* **14**, 3811–3817.
59. Scalise, M. *et al.* (2020) The human SLC1A5 neutral amino acid transporter catalyzes a pH-dependent glutamate/glutamine antiport, as well. *Front. Cell Dev. Biol.* **8**, 1–16.
60. Fairman, W. A., Vandenberg, R. J., Arriza, J. L., Kavanaugh, M. P. & Amara, S. G. (1995) An excitatory amino-acid transporter with properties of a ligand-gated chloride channel. *Nature* **375**, 599–603.
61. Wu, S. *et al.* (1998) Group III human metabotropic glutamate receptors 4, 7 and 8: Molecular cloning, functional expression, and comparison of pharmacological properties in RGT cells. *Mol. Brain Res.* **53**, 88–97.
62. Flor, P. J. *et al.* (1995) Molecular cloning, functional expression and pharmacological characterization of the human metabotropic glutamate receptor type 4. *Neuropharmacology* **34**, 149–155.
63. Arriza, J. L., Eliasof, S., Kavanaugh, M. P. & Amara, S. G. (1997) Excitatory amino acid transporter 5, a retinal glutamate transporter coupled to a chloride conductance. *Proc. Natl. Acad. Sci.* **94**, 4155–4160.
64. Daggett, L. P. *et al.* (1995) Molecular and functional characterization of recombinant human metabotropic glutamate receptor subtype 5. *Neuropharmacology* **34**, 871–886.
65. Bassi, M. T. *et al.* (2001) Identification and characterisation of human xCT that co-expresses, with 4F2 heavy chain, the amino acid transport activity system xc-. *Pflugers Arch. Eur. J. Physiol.* **442**, 286–296.
66. Laurie, D. J., Schoeffer, P., Wiederhold, K. H. & Sommer, B. (1997) Cloning, distribution and functional expression of the human mGlu6 metabotropic glutamate receptor. *Neuropharmacology* **36**, 145–152.
67. Miyaji, T., Omote, H. & Moriyama, Y. (2011) Functional characterization of vesicular excitatory amino acid transport by human sialin. *J. Neurochem.* **119**, 1–5.
68. Shigeri, Y., Seal, R. P. & Shimamoto, K. (2004) Molecular pharmacology of glutamate transporters, EAATs and VGLUTs. *Brain Res. Rev.* **45**, 250–265.
69. Fork, C. *et al.* (2011) OAT2 catalyses efflux of glutamate and uptake of orotic acid. *Biochem. J.* **436**, 305–312.
70. Skwara, P., Schömig, E. & Gründemann, D. (2017) A novel mode of operation of SLC22A11: Membrane insertion of estrone sulfate versus translocation of uric acid and glutamate. *Biochem. Pharmacol.* **128**, 74–82.
71. Lofthouse, E. M. *et al.* (2015) Glutamate cycling may drive organic anion transport on the basal membrane of human placental syncytiotrophoblast. *J. Physiol.* **593**, 4549–4559.
72. Schulz, C. *et al.* (2014) SLC22A13 catalyses unidirectional efflux of aspartate and glutamate at the basolateral membrane of type A intercalated cells in the renal collecting duct. *Biochem. J.* **457**, 243–251.
73. Loo, D. D. F., Eskandari, S., Boorer, K. J., Sarkar, H. K. & Wright, E. M. (2000) Role of Cl⁻ in electrogenic Na⁺-coupled cotransporters GAT1 and SGLT1. *J. Biol. Chem.* **275**, 37414–37422.
74. Kvist, T., Christiansen, B., Jensen, A. & Bräuner-Osborne, H. (2009) The four human γ -aminobutyric acid (GABA) transporters: pharmacological characterization and validation of a highly efficient screening assay. *Comb. Chem. High Throughput Screen.* **12**, 241–249.
75. Wood, M. D. *et al.* (2000) The human GABAB1b and GABAB2 heterodimeric recombinant receptor shows low sensitivity to pflaofen and saclofen. *Br. J. Pharmacol.* **131**, 1050–1054.
76. Richter, M., Moroniak, S. J. & Michel, H. (2019) Identification of competitive inhibitors of the human taurine transporter TauT in a human kidney cell line. *Pharmacol. Reports* **71**, 121–129.
77. Damgaard, M. *et al.* (2015) Identification of the first highly subtype-selective inhibitor of human GABA transporter GAT3. *ACS Chem. Neurosci.* **6**, 1591–1599.
78. Rasola, A., Galletta, L. J. V., Barone, V., Romeo, G. & Bagnasco, S. (1995) Molecular cloning and functional characterization of a GABA/betaine transporter from human kidney. *FEBS Lett.* **373**, 229–233.
79. Christiansen, B., Meinild, A. K., Jensen, A. A. & Bräuner-Osborne, H. (2007) Cloning and characterization of a functional human γ -aminobutyric acid (GABA) transporter, human GAT-2. *J. Biol. Chem.* **282**, 19331–19341.

80. Gasnier, B. (2004) The SLC32 transporter, a key protein for the synaptic release of inhibitory amino acids. *Pflugers Arch. Eur. J. Physiol.* **447**, 756–759.
81. Larsen, M., Larsen, B. B., Frølund, B. & Nielsen, C. U. (2008) Transport of amino acids and GABA analogues via the human proton-coupled amino acid transporter, hPAT1: Characterization of conditions for affinity and transport experiments in Caco-2 cells. *Eur. J. Pharm. Sci.* **35**, 86–95.
82. Kim, D. K. *et al.* (2002) The human T-type amino acid transporter-1: Characterization, gene organization, and chromosomal location. *Genomics* **79**, 95–103.
83. Lopez, V. M., Decatur, C. L., Stamer, W. D., Lynch, R. M. & McKay, B. S. (2008) L-DOPA is an endogenous ligand for OAT1. *PLoS Biol.* **6**, e236.
84. Damseh, N. *et al.* (2015) Mutations in SLC1A4, encoding the brain serine transporter, are associated with developmental delay, microcephaly and hypomyelination. *J. Med. Genet.* **52**, 541–547.
85. Wellendorph, P. *et al.* (2005) Deorphanization of GPRC6A: A promiscuous L- α -amino acid receptor with preference for basic amino acids. *Mol. Pharmacol.* **67**, 589–597.
86. Scalise, M. *et al.* (2014) Transport mechanism and regulatory properties of the human amino acid transporter ASCT2 (SLC1A5). *Amino Acids* **46**, 2463–2475.
87. Sloan, J. L. & Mager, S. (1999) Cloning and functional expression of a human Na⁺ and Cl⁻-dependent neutral and cationic amino acid transporter B0+. *J. Biol. Chem.* **274**, 23740–23745.
88. Takanaga, H., Mackenzie, B., Peng, J. Bin & Hediger, M. A. (2005) Characterization of a branched-chain amino-acid transporter SBAT1 (SLC6A15) that is expressed in human brain. *Biochem. Biophys. Res. Commun.* **337**, 892–900.
89. Kleta, R. *et al.* (2004) Mutations in SLC6A19, encoding B0AT1, cause Hartnup disorder. *Nat. Genet.* **36**, 999–1002.
90. Rossier, G. *et al.* (1999) LAT2, a new basolateral 4F2hc/CD98-associated amino acid transporter of kidney and intestine. *J. Biol. Chem.* **274**, 34948–34954.
91. Yan, R. *et al.* (2020) Cryo-EM structure of the human heteromeric amino acid transporter b0,+AT-rBAT. *Sci. Adv.* **6**, 1–11.
92. Nakauchi, J. *et al.* (2000) Cloning and characterization of a human brain Na⁺-independent transporter for small neutral amino acids that transports D-serine with high affinity. *Neurosci. Lett.* **287**, 231–235.
93. Pillai, S. M. & Meredith, D. (2011) SLC36A4 (hPAT4) is a high affinity amino acid transporter when expressed in *Xenopus laevis* oocytes. *J. Biol. Chem.* **286**, 2455–2460.
94. Bröer, S. (2014) The SLC38 family of sodium-amino acid co-transporters. *Pflugers Arch. Eur. J. Physiol.* **466**, 155–172.
95. Ramachandran, S. *et al.* (2021) Expression and function of SLC38A5, an amino acid-coupled Na⁺/H⁺ exchanger, in triple-negative breast cancer and its relevance to macropinocytosis. *Biochem. J.* **478**, 3957–3976.
96. Closs, E. I., Gräf, P., Habermeier, A., Cunningham, J. M. & Förstermann, U. (1997) Human cationic amino acid transporters hCAT-1, hCAT-2A, and hCAT-2B: Three related carriers with distinct transport properties. *Biochemistry* **36**, 6462–6468.
97. Vékony, N., Wolf, S., Boissel, J. P., Gnauret, K. & Closs, E. I. (2001) Human cationic amino acid transporter hCAT-3 is preferentially expressed in peripheral tissues. *Biochemistry* **40**, 12387–12394.
98. Bröer, A., Wagner, C. A., Lang, F. & Bröer, S. (2000) The heterodimeric amino acid transporter 4F2hc/y+LAT2 mediates arginine efflux in exchange with glutamine. *Biochem. J.* **349**, 787–795.
99. Torrents, D. *et al.* (1998) Identification and characterization of a membrane protein (y+L amino acid transporter-1) that associates with 4F2hc to encode the amino acid transport activity y+L. A candidate gene for lysinuric protein intolerance. *J. Biol. Chem.* **273**, 32437–32445.
100. Scalise, M. *et al.* (2019) Insights into the transport side of the human SLC38A9 transporter. *Biochim. Biophys. Acta - Biomembr.* **1861**, 1558–1567.
101. Werner, A. *et al.* (2017) Reconstitution of T cell proliferation under arginine limitation: Activated human T cells take up citrulline via L-Type amino acid transporter 1 and use it to regenerate arginine after induction of argininosuccinate synthase expression. *Front. Immunol.* **8**.
102. Yanagida, O. *et al.* (2001) Human L-type amino acid transporter 1 (LAT1): characterization of function and expression in tumor cell lines. *Biochim. Biophys. Acta - Biomembr.* **1514**, 291–302.
103. Fei, Y. J. *et al.* (2000) Primary structure genomic organization, and functional and electrogenic characteristics of human system N 1, a Na⁺- and H⁺-coupled glutamine transporter. *J. Biol. Chem.* **275**, 23707–23717.
104. Morrow, J. A. *et al.* (1998) Molecular cloning and functional expression of the human glycine transporter GlyT2 and chromosomal localisation of the gene in the human genome. *FEBS Lett.* **439**, 334–340.
105. Kim, K. M. *et al.* (1994) Cloning of the human glycine transporter type 1: Molecular and pharmacological characterization of novel isoform variants and chromosomal localization of the gene in the human and mouse genomes. *Mol. Pharmacol.* **45**, 608–617.

106. Bröer, S. *et al.* (2008) Iminoglycinuria and hyperglycinuria are discrete human phenotypes resulting from complex mutations in proline and glycine transporters. *J. Clin. Invest.* **118**, 3881–3892.
107. Devés, R. & Boyd, C. A. R. (1998) Transporters for cationic amino acids in animal cells: Discovery, structure, and function. *Physiol. Rev.* **78**, 487–545.
108. Babu, E. *et al.* (2003) Identification of a novel system L amino acid transporter structurally distinct from heterodimeric amino acid transporters. *J. Biol. Chem.* **278**, 43838–43845.
109. Boday, S. *et al.* (2005) Identification of LAT4, a novel amino acid transporter with system L activity. *J. Biol. Chem.* **280**, 12002–12011.
110. Liu, C. *et al.* (2015) GPR139, an orphan receptor highly enriched in the habenula and septum, is activated by the essential amino acids L-tryptophan and L-phenylalanine. *Mol. Pharmacol.* **88**, 911–925.
111. Lu, R., Kanai, N., Bao, Y. & Schuster, V. L. (1996) Cloning, in vitro expression, and tissue distribution of a human prostaglandin transporter cDNA (hPGT). *J. Clin. Invest.* **98**, 1142–1149.
112. Abramovitz, M. *et al.* (2000) The utilization of recombinant prostanoid receptors to determine the affinities and selectivities of prostaglandins and related analogs. *Biochim. Biophys. Acta - Mol. Cell Biol. Lipids* **1483**, 285–293.
113. Wright, D. H., Metters, K. M., Abramovitz, M. & Ford-Hutchinson, A. W. (1998) Characterization of the recombinant human prostanoid DP receptor and identification of L-644,698, a novel selective DP agonist. *Br. J. Pharmacol.* **123**, 1317–1324.
114. Adachi, H. *et al.* (2003) Molecular characterization of human and rat organic anion transporter OATP-D. *Am. J. Physiol. - Ren. Physiol.* **285**, 1188–1197.
115. Sharif, N. A. & Davis, T. L. (2002) Cloned human EP1 prostanoid receptor pharmacology characterized using radioligand binding techniques. *J. Pharm. Pharmacol.* **54**, 539–547.
116. Bastien, L., Sawyer, N., Grygorczyk, R., Metters, K. M. & Adam, M. (1994) Cloning, functional expression, and characterization of the human prostaglandin E2 receptor EP2 subtype. *J. Biol. Chem.* **269**, 11873–11877.
117. Davis, T. L. & Sharif, N. A. (2000) Pharmacological characterization of [³H]-prostaglandin E2 binding to the cloned human EP4 prostanoid receptor. *Br. J. Pharmacol.* **130**, 1919–1926.
118. Stitham, J. *et al.* (2007) New insights into human prostacyclin receptor structure and function through natural and synthetic mutations of transmembrane charged residues. *Br. J. Pharmacol.* **152**, 513–522.
119. Gose, T. *et al.* (2016) Prostaglandin transporter (OATP2A1/SLCO2A1) contributes to local disposition of eicosapentaenoic acid-derived PGE₃. *Prostaglandins Other Lipid Mediat.* **122**, 10–17.
120. Kimura, H. *et al.* (2002) Human organic anion transporters and human organic cation transporters mediate renal transport of prostaglandins. *J. Pharmacol. Exp. Ther.* **301**, 293–298.
121. Wada, M. *et al.* (2007) Enzymes and receptors of prostaglandin pathways with arachidonic acid-derived versus eicosapentaenoic acid-derived substrates and products. *J. Biol. Chem.* **282**, 22254–22266.
122. Murakami, Y. *et al.* (2005) Functional characterization of human monocarboxylate transporter 6 (SLC16A5). *Drug Metab. Dispos.* **33**, 1845–1851.
123. Coady, M. J. *et al.* (2004) The human tumour suppressor gene SLC5A8 expresses a Na⁺-monocarboxylate cotransporter. *J. Physiol.* **557**, 719–731.
124. Ahmed, K. *et al.* (2010) An autocrine lactate loop mediates insulin-dependent inhibition of lipolysis through GPR81. *Cell Metab.* **11**, 311–319.
125. Gopal, E. *et al.* (2007) Cloning and functional characterization of human SMCT2 (SLC5A12) and expression pattern of the transporter in kidney. *Biochim. Biophys. Acta - Biomembr.* **1768**, 2690–2697.
126. Bosshart, P. D., Charles, R., Garibsingh, R. A., Schlessinger, A. & Fotiadis, D. (2021) SLC16 family: From atomic structure to human disease. *Trends Biochem. Sci.* **46**, 28–40.
127. Gopal, E. *et al.* (2007) Transport of nicotinate and structurally related compounds by human SMCT1 (SLC5A8) and its relevance to drug transport in the mammalian intestinal tract. *Pharm. Res.* **24**, 575–584.
128. Wise, A. *et al.* (2003) Molecular identification of high and low affinity receptors for nicotinic acid. *J. Biol. Chem.* **278**, 9869–9874.
129. Taggart, A. K. P. *et al.* (2005) (D)-β-hydroxybutyrate inhibits adipocyte lipolysis via the nicotinic acid receptor PUMA-G. *J. Biol. Chem.* **280**, 26649–26652.
130. Mathialagan, S. *et al.* (2020) Nicotinic acid transport into human liver involves organic anion transporter 2 (SLC22A7). *Biochem. Pharmacol.* **2**, 113829.
131. Ho, J. S. *et al.* (2007) Novel liver-specific organic anion transporter OAT17 that operates the exchange of sulfate conjugates for short chain fatty acid butyrate. *Hepatology* **45**, 1046–1055.
132. Bahn, A. *et al.* (2008) Identification of a new urate and high affinity nicotinate transporter, hOAT10 (SLC22A13). *J. Biol. Chem.* **283**, 16332–16341.

133. Brown, A. J. *et al.* (2003) The orphan G protein-coupled receptors GPR41 and GPR43 are activated by propionate and other short chain carboxylic acids. *J. Biol. Chem.* **278**, 11312–11319.
134. Miyachi, S., Gopal, E., Fei, Y. J. & Ganapathy, V. (2004) Functional identification of SLC5A8, a tumor suppressor down-regulated in colon cancer, as a Na⁺-coupled transporter for short-chain fatty acids. *J. Biol. Chem.* **279**, 13293–13296.
135. Martin, P. M. *et al.* (2006) Identity of SMCT1 (SLC5A8) as a neuron-specific Na⁺-coupled transporter for active uptake of L-lactate and ketone bodies in the brain. *J. Neurochem.* **98**, 279–288.
136. Pajor, A. M. (2014) Sodium-coupled dicarboxylate and citrate transporters from the SLC13 family. *Pflügers Arch. - Eur. J. Physiol.* **466**, 119–130.
137. He, W. *et al.* (2004) Citric acid cycle intermediates as ligands for orphan G-protein-coupled receptors. *Nature* **429**, 188–193.
138. Prag, H. A. *et al.* (2021) Mechanism of succinate efflux upon reperfusion of the ischaemic heart. *Cardiovasc. Res.* **117**, 1188–1201.
139. Reddy, A. *et al.* (2020) pH-gated succinate secretion regulates muscle remodeling in response to exercise. *Cell* **183**, 62–75.
140. Bisbach, C. M., Hass, D. T., Thomas, E. D., Cherry, T. J. & Hurley, J. B. (2022) Monocarboxylate transporter 1 (MCT1) mediates succinate export in the retina. *Investig. Ophthalmology Vis. Sci.* **63**, 1.
141. Kaufhold, M. *et al.* (2011) Differential interaction of dicarboxylates with human sodium-dicarboxylate cotransporter 3 and organic anion transporters 1 and 3. *Am. J. Physiol. - Ren. Physiol.* **301**, 1026–1034.
142. Wang, Z. *et al.* (2020) Mfsd2a and Spns2 are essential for sphingosine-1-phosphate transport in the formation and maintenance of the blood-brain barrier. *Sci. Adv.* **6**, eaay8627.
143. Im, D. S., Clemens, J., Macdonald, T. L. & Lynch, K. R. (2001) Characterization of the human and mouse sphingosine 1-phosphate receptor, SIP5 (Edg-8): Structure–activity relationship of sphingosine 1-phosphate receptors. *Biochemistry* **40**, 14053–14060.
144. Pan, S. *et al.* (2006) A monoselective sphingosine-1-phosphate receptor-1 agonist prevents allograft rejection in a stringent rat heart transplantation model. *Chem. Biol.* **13**, 1227–1234.
145. Vu, T. M. *et al.* (2017) Mfsd2b is essential for the sphingosine-1-phosphate export in erythrocytes and platelets. *Nature* **550**, 524–528.
146. Hisano, Y., Kobayashi, N., Kawahara, A., Yamaguchi, A. & Nishi, T. (2011) The sphingosine 1-phosphate transporter, SPNS2, functions as a transporter of the phosphorylated form of the immunomodulating agent FTY720. *J. Biol. Chem.* **286**, 1758–1766.
147. Uhlenbrock, K., Gassenhuber, H. & Kostenis, E. (2002) Sphingosine 1-phosphate is a ligand of the human gpr3, gpr6 and gpr12 family of constitutively active G protein-coupled receptors. *Cell. Signal.* **14**, 941–953.
148. Niedernberg, A., Tunaru, S., Blaukat, A., Ardati, A. & Kostenis, E. (2003) Sphingosine 1-phosphate and dioleoylphosphatidic acid are low affinity agonists for the orphan receptor GPR63. *Cell. Signal.* **15**, 435–446.
149. Murakami, M., Shiraishi, A., Tabata, K. & Fujita, N. (2008) Identification of the orphan GPCR, P2Y10 receptor as the sphingosine-1-phosphate and lysophosphatidic acid receptor. *Biochem. Biophys. Res. Commun.* **371**, 707–712.
150. Hagenbuch, B. & Meier, P. J. (1994) Molecular cloning, chromosomal localization, and functional characterization of a human liver Na⁺/bile acid cotransporter. *J. Clin. Invest.* **93**, 1326–1331.
151. Kawamata, Y. *et al.* (2003) A G protein-coupled receptor responsive to bile acids. *J. Biol. Chem.* **278**, 9435–9440.
152. Craddock, A. L. *et al.* (1998) Expression and transport properties of the human ileal and renal sodium-dependent bile acid transporter. *Am. J. Physiol. - Gastrointest. Liver Physiol.* **274**, 157–169.
153. Liu, R. *et al.* (2015) Taurocholate induces cyclooxygenase-2 expression via the sphingosine 1-phosphate receptor 2 in a human cholangiocarcinoma cell line. *J. Biol. Chem.* **290**, 30988–31002.
154. Yee, S. W. *et al.* (2019) Unraveling the functional role of the orphan solute carrier, SLC22A24 in the transport of steroid conjugates through metabolomic and genome-wide association studies. *PLoS Genet.* **15**, e1008208.
155. Suga, T., Yamaguchi, H., Ogura, J. & Mano, N. (2019) Characterization of conjugated and unconjugated bile acid transport via human organic solute transporter α/β . *Biochim. Biophys. Acta - Biomembr.* **1861**, 1023–1029.
156. Kullak-Ublick, G. A. *et al.* (1995) Molecular and functional characterization of an organic anion transporting polypeptide cloned from human liver. *Gastroenterology* **109**, 1274–1282.
157. Suga, T. *et al.* (2017) Preference of conjugated bile acids over unconjugated bile acids as substrates for OATP1B1 and OATP1B3. *PLoS One* **12**, e0169719.
158. Pan, Q. *et al.* (2018) Solute carrier organic anion transporter family member 3A1 is a bile acid efflux transporter in cholestasis. *Gastroenterology* **155**, 1578–1592.
159. Gimeno, R. E. *et al.* (2003) Characterization of a heart-specific fatty acid transport protein. *J. Biol. Chem.* **278**, 16039–16044.
160. Schaffer, J. E. & Lodish, H. F. (1994) Expression cloning and characterization of a novel adipocyte long chain fatty acid transport protein. *Cell* **79**, 427–436.

161. Itoh, Y. *et al.* (2003) Free fatty acids regulate insulin secretion from pancreatic β cells through GPR40. *Nature* **422**, 173–176.
162. Briscoe, C. P. *et al.* (2003) The orphan G protein-coupled receptor GPR40 is activated by medium and long chain fatty acids. *J. Biol. Chem.* **278**, 11303–11311.
163. Falcon, A. *et al.* (2010) FATP2 is a hepatic fatty acid transporter and peroxisomal very long-chain acyl-CoA synthetase. *Am. J. Physiol. - Endocrinol. Metab.* **299**, 384–393.
164. Watson, S. J., Brown, A. J. H. & Holliday, N. D. (2012) Differential signaling by splice variants of the human free fatty acid receptor GPR120. *Mol. Pharmacol.* **81**, 631–642.
165. Stahl, A. *et al.* (1999) Identification of the major intestinal fatty acid transport protein. *Mol. Cell* **4**, 299–308.
166. Alexander, S. P. H. *et al.* (2021) The concise guide to pharmacology 2021/22: Transporters. *Br. J. Pharmacol.* **178**, S412–S513.

