Ferret model tables

Table S1:

Populations				
Name	**Description**	**% of total model (Ferret)**	**% of total model (Multiregion)**	**Compartments**
P23	Pyramidal neurons in layer 2-3 (L2-3)	27.41	80	8
B23	Basket interneurons in L2-3	3.27	10	7
NB23	Non-basket interneuron in L2-3	2.25	-	7
SS4(-4)	Spiny stellate neurons in L4 projecting to L4	9.67	-	7
SS4(-23)	Spiny stellate neurons in L4 projecting to L2-3	9.67	-	7
P4	Pyramidal neurons in L4	9.67	-	8
B4	Basket interneurons in L4	5.68	-	7
NB4	Non-basket interneuron in L4	1.58	-	7
P5(-23)	Pyramidal neurons in layer 5 projecting to L2-3	5	-	9
P5(-56)	Pyramidal neurons in layer 5 projecting to L5&6	1.36	-	9
B5	Basket interneurons in L5	0.63	-	7
NB5	Non-basket interneuron in L5	0.84	-	7
P6(-4)	Pyramidal neurons in layer 6 projecting to L4	14.13	-	9
P6(-56)	Pyramidal neurons in layer 6 projecting to L5&6	4.68	-	9
B6	Basket interneurons in L6	4.16	-	7
Dummy Neurons	Placeholder neurons for the interregional connections	-	10	8

Table S2:

Topology	
Topology can be user defined in VERTEX. The Ferret model has five layers, with sizes shown below.	
Layer (Ferret model)	**Depth (micrometers)**
1	182
2/3	367
4	346
5	105
6	240

Table S3:

Connectivity
All populations have randomised connections to other populations, with connection probabilities, synaptic weights and target compartment locations user defined. In the Ferret model these connections are based on biological data, and connectivity parameter details are shown in figures S1 and S2, taken from [1].

Table S4: For further detail see the supplementary material in [1], the equations in the table are taken from the description in this paper. The parameters mentioned in the dynamics equations represent the following: V_s is the soma membrane potential, V_k is the dendritic membrane potential. Similarly, subscript 'k' and 's' represent the dendritic or soma version of the following parameters where relevant. C is the membrane capacitance, g_{leak} is the leak conductance (the reciprocal of the membrane resistance), E_{leak} is the leak reversal potential. The conductances between the soma/dendrites and their connected 'jth' compartments are represented by $g_{s,j}$ and $g_{k,j}$ respectively. Δ_t is a constant which determines the spike steepness, V_t the instantaneous threshold potential and w represents the combined slow and ionic currents, it has a time constant τ_w and scale factor α. The total current input is represented by I. The potential at which a spike is considered to fire is v_{cutoff}, after a spike v_s resets to the membrane potential given in v_{reset}. The change in the slow current w after a spike is set by β.

Neuron Model	
Name	AdEx
Type	Adaptive Exponential neuron model used in the soma, with passive dendrite dynamics.
Soma Dynamics	$C_s \frac{dv_s}{dt} = -g_{leak,s}(v_s - E_{leak}) - \sum_j g_{sj}(v_s - v_j) + g_{leak,s}\Delta_t exp(\frac{v_s - V_t}{\Delta_t}) - w + I_s$, $\tau_w \frac{dw}{dt} = \alpha(v_s - E_{leak}) - w$, if $v_s \geq v_{cutoff}$: $v_s \leftarrow v_{reset}$, $w \leftarrow w + \beta$,
Dendrite Dynamics	$C_k \frac{dv_k}{dt} = -g_{leak,k}(v_k - E_{leak}) - \sum_j g_{kj}(v_k - v_j) + I_k$

Table S5:

Synapse Models	
AMPA, GABAa	If a spike occurs synaptic conductance g for the given synapse type at a contacted target compartment k (specified in the connectivity matrix) is increased by the relevant synaptic weight after the relevant axonal delay time. The synapses then decay exponentially: $\frac{dg_{AMPA,k}}{dt} = -\frac{g_{AMPA,k}}{\tau_{AMPA}}$, $\frac{dg_{GABA,k}}{dt} = -\frac{g_{GABA,k}}{\tau_{AMPA}}$ The total synaptic current I_k at compartment k at time t is: $I_k(t) = g_{AMPA,k}(v_k(t)E_{AMPA}) + g_{GABA,k}(v_k(t)E_{GABA})$.

Table S6:

Input	
Type	**Description**
Random inputs	Each neuron population is given a mean and standard deviation to seed a normally distributed random input. The parameters used vary for different background behaviour, see table S8 for details.
Electric field stimulation	The electric field is inputed as a finite element model and field values are interpolated for each neuron. See the methods section in Chapter **??** for further details.
Step current	An input is added via the total current input parameter in the neuron model equations for a user defined amplitude and length of time.

Table S7:

Measurements	
Measure	**Detail**
Spikes	Spike activity for all neurons, with Neuron IDs and time points to allow raster plots.
LFP	LFPs from user defined electrode locations, sampled at 1kHz.
V_m	Membrane potentials over time from user specified neurons (by ID) and compartments.

Table S8: **Parameter table for the ferret visual cortex model.** The synaptic delays are applied generically depending on the connection type between excitatory (E) or inhibitory (I) population types. The noise inputs were applied for the individual neuron populations, these are shown with an abbreviated type followed by the layer the neuron type is present in, e.g. P23 indicates layer 2/3 pyramidal cells. B indicates basket interneuron, NB indicates non-basket interneuron, SS indicates excitatory spiny stellate cells. The number in brackets after some entries distinguishes between populations which have differing projections, i.e. SS4(-4) indicates spiny stellate cells in layer 4 which project to layer 4. This table shows the differences for the alternative background oscillation types. For the full model parameters the full code is available for download at `https://github.com/Fehings/Vertex_git.git`

Parameter	Slow Oscillations	Parameter	Slow Oscillations
Synaptic delay: E-E	5.5	Synaptic delay: I-E	24
Synaptic delay: E-I	14.25	Synaptic delay: I-I	34
Mean noise input P23	220	Std noise input P23	110
Mean noise input B23	100	Std noise input B23	60
Mean noise input NB23	120	Std noise input NB23	40
Mean noise input SS4(-4)	185	Std noise input SS4(-4)	50
Mean noise input SS4(-23)	185	Std noise input SS4(-23)	50
Mean noise input P4	200	Std noise input P4	70
Mean noise input B4	100	Std noise input B4	60
Mean noise input NB4	120	Std noise input NB4	40
Mean noise input P5(-23)	590	Std noise input P5(-23)	260
Mean noise input P5(-56)	590	Std noise input P5(-56)	260
Mean noise input B5	100	Std noise input B5	60
Mean noise input NB5	120	Std noise input NB5	40
Mean noise input P6(-4)	660	Std noise input P6(-4)	470
Mean noise input P6(-56)	660	Std noise input P6(-56)	470
Mean noise input B6	100	Std noise input B6	60

Presynaptic neurons

Postsynaptic neurons		percent of cells	max no. synapses	p23	b23	nb23	ss4(L4)	ss4(L23)	p4	b4	nb4	p5(L23)	p5(L56)	b5	nb5	p6(L4)	p6(L56)	b6
P23	L23	26.3	5773	60.1	9.2	4.9	0.6	6.9	7.8	0.8	-	7.5	-	-	-	2.4	-	-
	L1		87	95.1	1.6	-	-	0.3	1.5	0.1	-	1.1	-	-	-	-	-	-
B23		3.1	3702	53.7	11.0	12.3	0.5	6.1	6.8	0.9	-	6.6	-	-	-	2.1	-	-
NB23		4.2	3144	57.8	12.6	4.6	0.5	6.6	7.5	0.9	-	7.2	-	-	-	2.2	-	-
SS4(L4)		9.3	4113	3.8	0.3	-	16.7	5.2	5.8	12.9	8.1	1.1	0.1	-	-	46.1	-	-
SS4(L23)		9.3	3610	7.7	0.6	-	15.6	5.3	5.9	12.8	7.6	1.5	0.1	-	-	43.0	-	-
P4	L4	9.3	3619	6.0	0.3	-	16.0	5.0	5.8	12.9	8.3	1.6	0.1	0.1	-	43.7	0.1	-
	L23		867	63.0	5.1	5.1	0.6	7.2	8.1	0.6	-	7.8	-	-	-	2.5	-	-
	L1		53	6.0	0.3	-	16.0	5.0	5.8	12.9	8.3	1.6	0.1	0.1	-	43.7	0.1	-
B4		5.5	2359	8.0	0.7	-	15.1	5.2	5.8	14.8	7.3	1.5	0.1	-	-	41.6	-	-
NB4		1.5	2636	3.7	0.3	-	16.3	5.1	5.6	14.8	7.9	1.1	0.1	-	-	45.0	-	-
P5(L23)	L5	4.9	3971	49.9	2.0	-	3.6	2.2	8.2	1.0	-	12.7	1.1	2.1	12.5	2.5	2.2	-
	L4		198	4.0	0.1	-	17.4	5.4	6.0	9.5	8.4	1.1	0.1	-	-	48.0	-	-
	L23		413	62.9	5.1	5.1	0.6	7.2	8.1	0.6	-	7.8	-	-	-	2.4	-	-
	L1		12	97.7	1.7	-	-	0.3	1.5	0.1	-	1.1	-	-	-	-	-	-
P5(L56)	L5	1.3	4588	49.3	1.8	-	3.6	2.2	8.1	0.9	-	12.5	1.3	2.0	13.0	2.5	2.8	-
	L4		666	4.0	0.1	-	17.4	5.4	6.0	9.5	8.4	1.1	0.1	-	-	48.0	-	-
	L23		1368	63.0	5.1	5.1	0.6	7.2	8.1	0.6	-	7.8	-	-	-	2.5	-	-
	L1		375	95.6	1.7	-	-	0.3	1.5	0.1	-	1.1	-	-	-	-	-	-
B5		0.6	2744	49.5	2.5	-	3.6	2.2	8.1	1.2	-	12.6	1.1	2.3	12.3	2.5	2.2	-
NB5		0.8	2744	49.5	2.5	-	3.6	2.2	8.1	1.2	-	12.6	1.1	2.3	12.3	2.5	2.2	-
P6(L4)	L6	13.8	1326	6.1	0.3	-	1.8	2.1	3.1	0.2	-	0.2	12.0	0.9	-	2.9	32.4	38.1
	L5		979	51.0	0.9	-	3.7	2.3	8.4	0.6	-	13.0	1.1	1.6	12.7	2.5	2.3	-
	L4		1344	4.0	0.1	-	17.4	5.4	6.0	9.5	8.4	1.1	0.1	-	-	48.0	-	-
	L23		121	62.9	5.1	5.1	0.6	7.2	8.1	0.6	-	7.8	-	-	-	2.4	-	-
P6(L56)	L6	4.6	2264	4.0	0.1	-	17.4	5.4	6.0	9.5	8.4	1.1	0.1	-	-	48.0	-	-
	L5		236	51.0	0.9	-	3.7	2.3	8.4	0.6	-	13.0	1.1	1.6	12.7	2.5	2.3	-
	L4		171	4.0	0.1	-	17.4	5.4	6.0	9.4	8.4	1.1	0.1	-	-	47.8	-	-
	L23		286	63.1	5.1	5.1	0.6	7.2	8.1	0.6	-	7.8	-	-	-	2.5	-	-
	L1		4	97.7	1.7	-	-	0.3	1.5	0.1	-	1.1	-	-	-	-	-	-
B6		2.0	1310	6.1	0.3	-	1.8	2.1	3.1	0.2	-	0.2	12.0	0.9	-	2.9	32.4	38.1

Figure S1: This table was published in [2, 1], with the following caption information. The same connectivity was used in the Ferret model, as the data used to inform the connectivity is taken from existing biological data. The table shows the neuron population sizes given as percentage of the total model size. Pyramidal neurons have apical dendrites spanning several cortical layers, so the maximum number of synapses received is specified per-layer for them. The proportions of the recieved synapses made by each presynaptic neuron group are given in percentages of the maximal synapse numbers. Slice cutting effects are replicated by having neurons in the slice model receive fewer than the maximum possible synapses. This data was adapted from [3] with the long-range connections removed. In the single layer model used in the multiregion simulations there are only three populations, pyramidal (P), basket interneurons (B) and the dummy neurons (D). In this model the total numbers of synapses are P: 2300, B: 1600, D:3000. The percentage of synapses from these presynaptic groups are P→P= 73.91, P→B= 26.09, B→B= 37.5, B→P= 62.5, D→P= 100.

Presynaptic neurons

Postsynaptic neurons	P23	B23	NB23	SS4(L4)	SS4(L23)	P4	B4	NB4	P5(L23)	P5(L5/6)	B5	NB5	P6(L4)	P6(L5/6)	B6
P23	0.020	0.126	0.001	0.356	0.036	0.073	1.080	-	0.004	-	-	-	0.047	-	-
B23	0.560	0.026	0.001	0.701	0.078	0.161	0.228	-	0.074	-	-	-	0.159	-	-
NB23	0.408	0.069	0.014	0.872	0.085	0.173	0.581	-	0.159	-	-	-	0.178	-	-
SS4(L4)	0.001	0.043	-	0.067	0.092	0.061	0.010	0.003	0.069	0.069	-	-	0.004	-	-
SS4(L23)	0.001	0.043	-	0.067	0.092	0.061	0.011	0.003	0.069	0.069	-	-	0.004	-	-
P4	0.001	0.043	0.008	0.067	0.092	0.061	0.014	0.001	0.069	0.069	-	-	0.004	0.004	-
B4	0.101	0.098	-	0.627	0.627	0.627	0.025	0.003	0.841	0.841	-	-	0.062	0.062	-
NB4	0.139	0.244	-	0.318	0.318	0.318	0.068	0.013	1.058	1.058	-	-	0.052	-	-
P5(L23)	0.037	0.188	0.004	0.091	0.082	0.050	0.341	0.005	0.079	0.471	0.459	0.003	0.032	0.093	-
P5(L5/6)	0.037	0.188	0.004	0.091	0.082	0.050	0.289	0.005	0.062	0.335	0.416	0.003	0.032	0.093	-
B5	0.083	0.098	-	0.274	0.273	0.151	0.191	-	0.910	3.966	0.166	0.003	0.342	0.207	-
NB5	0.064	0.244	-	0.331	0.422	0.196	0.521	-	0.603	2.596	0.166	0.014	0.359	0.657	-
P6(L4)	0.003	1.045	0.015	0.137	0.145	0.095	0.226	0.001	0.084	0.055	0.293	0.004	0.064	0.062	0.075
P6(L5/6)	0.003	1.045	0.015	0.137	0.145	0.095	0.978	0.016	0.201	0.055	0.293	0.004	0.064	0.062	0.048
B6	0.123	0.140	-	0.274	0.273	0.151	0.193	-	0.091	0.091	0.021	-	1.105	0.768	0.015

Figure S2: This table was published in [2, 1] and is repeated here as the same parameters were used in the Ferret model in this paper. In the layer 2-3 model used in the multiregion simulations the weights are slightly different. There are only three populations, pyramidal (P), basket interneurons (B) and the dummy neurons (D): P→P= 0.05, P→B= 0.1, B→B= 0.2, B→P= 0.2, D→P= 0.5.

Presynaptic neurons

Postsynaptic neurons	P2/3, P4	SS	P5	P6	B	NB
P2/3, P4	3,6,7,8	6-8	4,5	4	1,2,6	3-5,7,8
SS4	3,4,6,7	3,4,6,7	3,4,6,7	3,4,6,7	1,2,5	3,4,6,7
P5	2-9	2-5	2-5,7-9	2-5,7-9	1,2,7	3-5,7,8
P6	2-9	2,4,5	2-9	2-9	1,2,7	3-5,7,8
B	3,4,6,7	3,4,6,7	3,4,6,7	3,4,6,7	3,4,6,7	3,4,6,7
NB	3,4,6,7	3,4,6,7	3,4,6,7	3,4,6,7	3,4,6,7	3,4,6,7

Figure S3: This table was published in [2, 1] and is repeated here as the same parameters were used in the Ferret model in this paper. In the layer 2-3 model the compartment targets are slightly different. P→P and D→P compartment targets are 2345678. P→B and B→B target 234567, while B→P targets the soma compartment 1.

Neuron type	C_m **(μFcm^{-2})**	R_m **(kΩcm^2)**	R_a **(Ωcm)**	E_l **(mV)**	V_T **(mV)**	Δ_T **(mV)**	α **(nS)**	τ_w **(ms)**	β **(pA)**	v_{reset} **(mV)**
P2/3, P4	2.96	6.76	150	-70	-50	2.0	2.60	65	220	-60
SS4	2.95	5.12	150	-70	-50	2.2	0.35	150	40	-70
P5	2.95	6.78	150	-70	-52	2.0	10.00	75	345	-62
P6	2.95	6.78	150	-70	-50	2.0	0.35	160	60	-60
B	2.93	5.12	150	-70	-50	2.0	0.04	10	40	-65
NB	2.93	5.12	150	-70	-55	2.2	0.04	75	75	-62

Figure S4: This table was published in [2, 1] and is repeated here as the same parameters were used in all of the VERTEX simulations conducted in this paper. Additionally worthy of mention, the time step used in all simulations was 0.03125 ms.

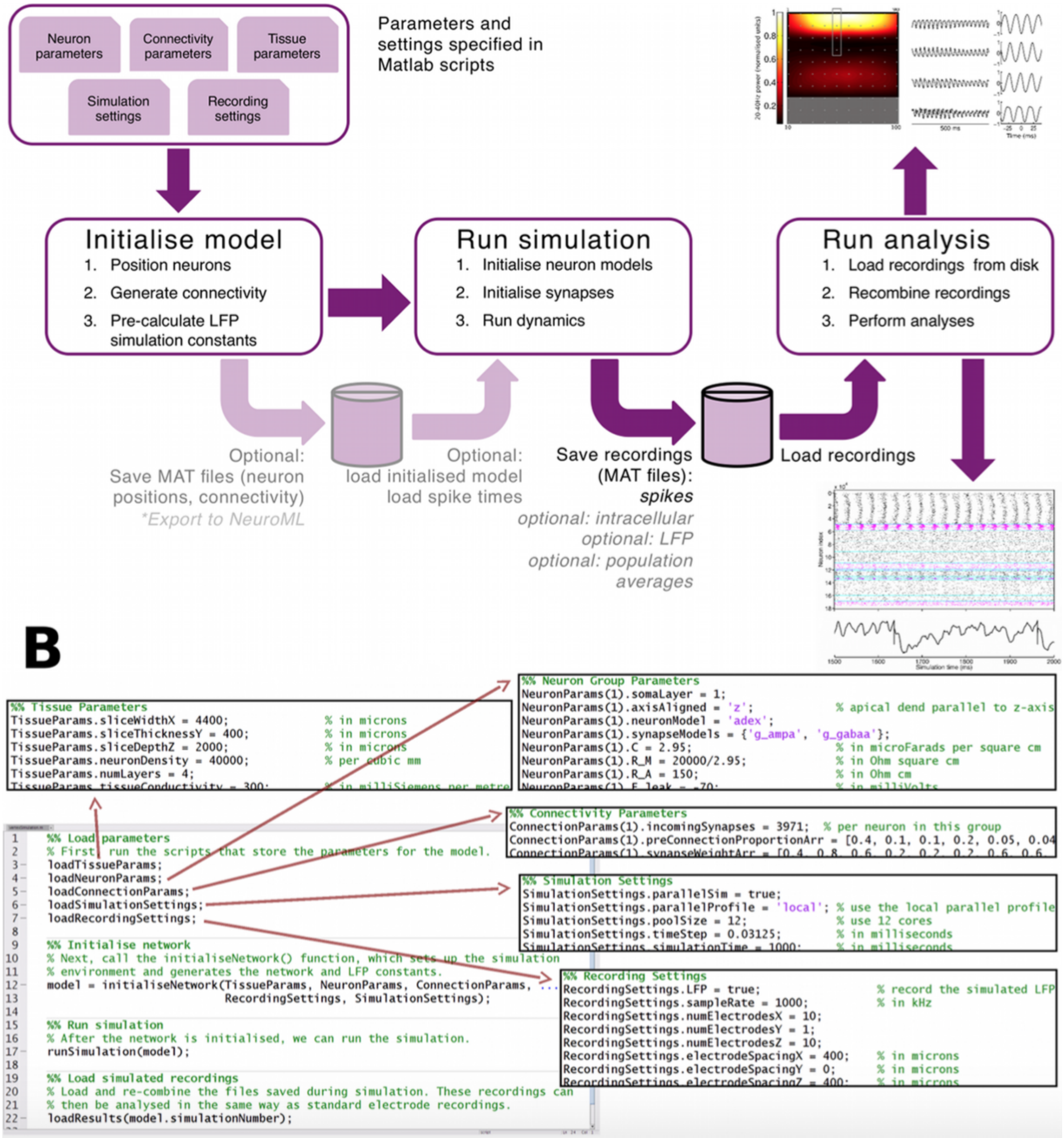

Figure S5: This schematic was published in [2, 1] and is repeated here as a useful overview of the VERTEX simulator for the reader.

References

[1] R. J. Tomsett, M. Ainsworth, A. Thiele, M. Sanayei, X. Chen, M. A. Gieselmann, M. A. Whittington, M. O. Cunningham, M. Kaiser, Virtual Electrode Recording Tool for EXtracellular potentials (VERTEX): comparing multi-electrode recordings from simulated and biological mammalian cortical tissue, Brain Structure and Function 220 (4) (2015) 2333–2353. doi:10.1007/s00429-014-0793-x.

[2] R. J. Tomsett, A novel simulation framework for modelling extracellular recordings in cortical tissue: implementation, validation, and application to gamma oscillations in mammals, Phd thesis, Newcastle University (2014).

[3] T. Binzegger, R. J. Douglas, K. A. C. Martin, A Quantitative Map of the Circuit of Cat Primary Visual Cortex, Journal of Neuroscience 24 (39).