Mapping Function onto Neuronal Morphology

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Neurons have a wide range of dendritic morphologies, whose functions are largely unknown. We used an optimization procedure to find neuronal morphological structures for two computational tasks: First, neuronal morphologies were selected for the task of summing excitatory synaptic potentials (EPSPs) linearly. Second, structures were selected that distinguished the temporal order of EPSPs. We used genetic algorithms and Lindenmayer-systems in our optimization procedure.
The solutions resembled the morphology of real neurons. In particular the neurons optimized for linear summation electrotonically separated their synapses, as found in avian *nucleus laminaris* neurons. Neurons optimized for spike order detection had primary dendrites of significantly different diameter, as found in the basal and apical dendrites of cortical pyramidal neurons.
We have therefore achieved an automated mapping between neuronal function and structure. This method allows a large catalog of computational functions to be built indexed by morphological structure.

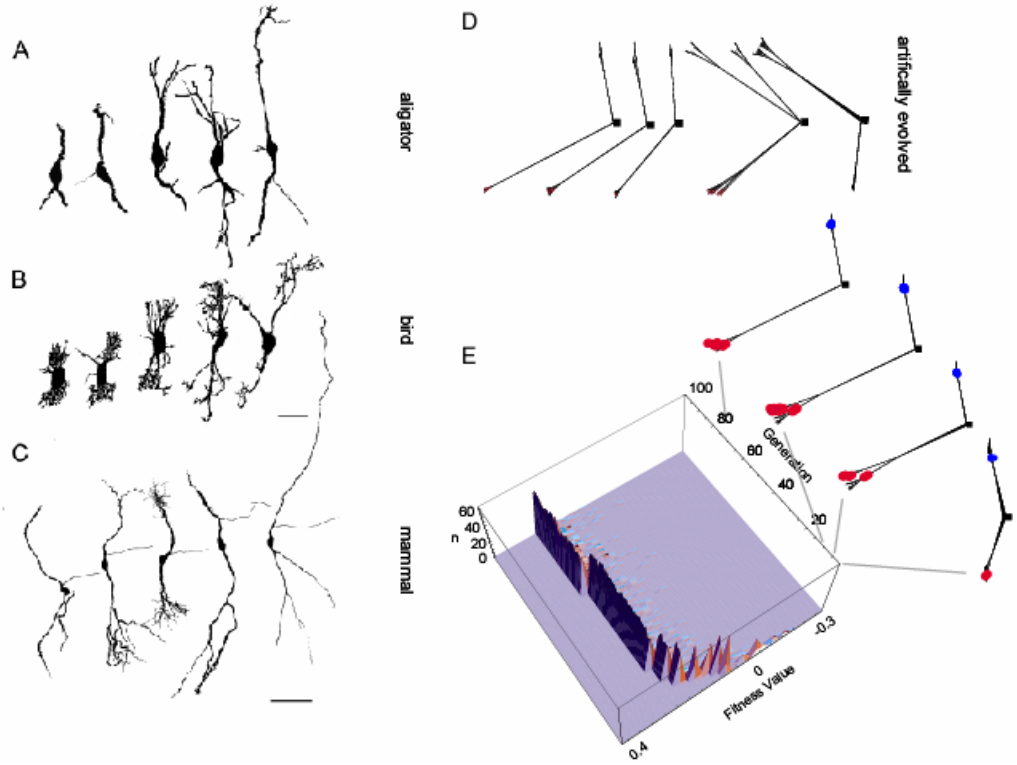

Figure: Selection for linear summation. For comparison: Morphology of synaptically early auditory brainstem coincidence detector neurons. Golgi-stained neurons from an alligator nucleus laminaris **(A)**, a bird nucleus laminaris **(B)** and a mammalian medial superior olive **(C)**. A–C from Carr et al., 2005. **(D)** Neurons optimized for linear summation of 2 groups of coincident inputs. The best performing neurons after 400 generations from 5 simulation runs with different random number generator seeds are shown. **(E)** Time course of the optimization. Simulations using a genetic algorithm with 64 genomes and 400 generations. Time-resolved fitness-histograms (only the first 100 generations are shown). The number of genomes, n, in the vertical axis is plotted as a function of generation and fitness. Morphologies of the best solutions from at different stages of the artificial evolution are shown.