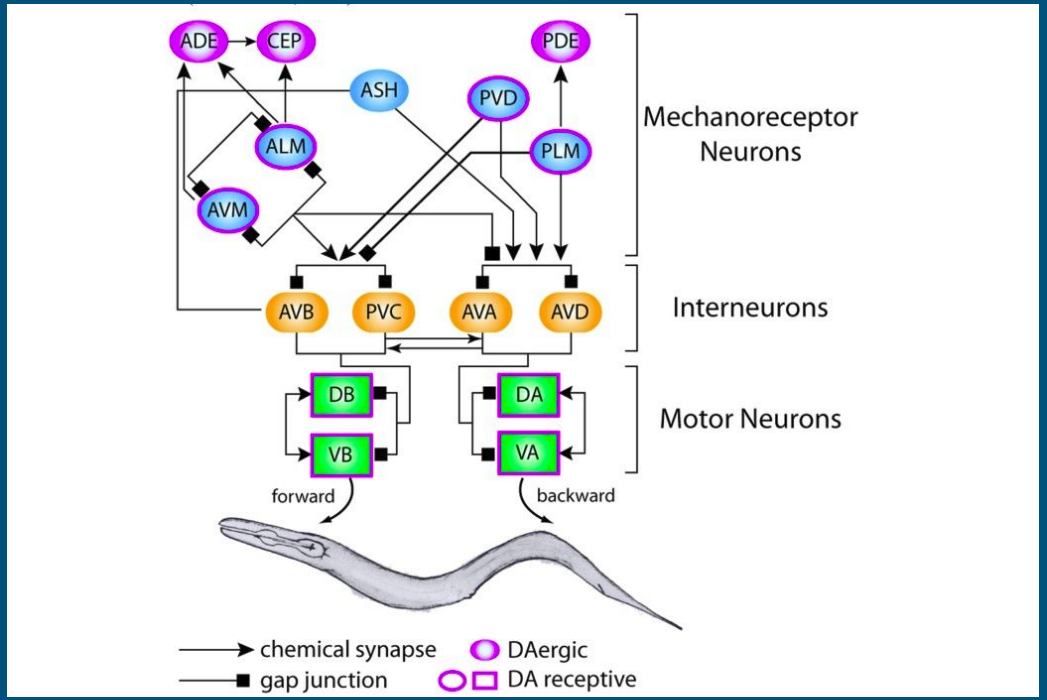
C. elegans - from mechanosensor to motor neuron

Finding a neural circuit to simulate with Arbor and NEURON

A neural circuit that links mechanosensation to locomotion

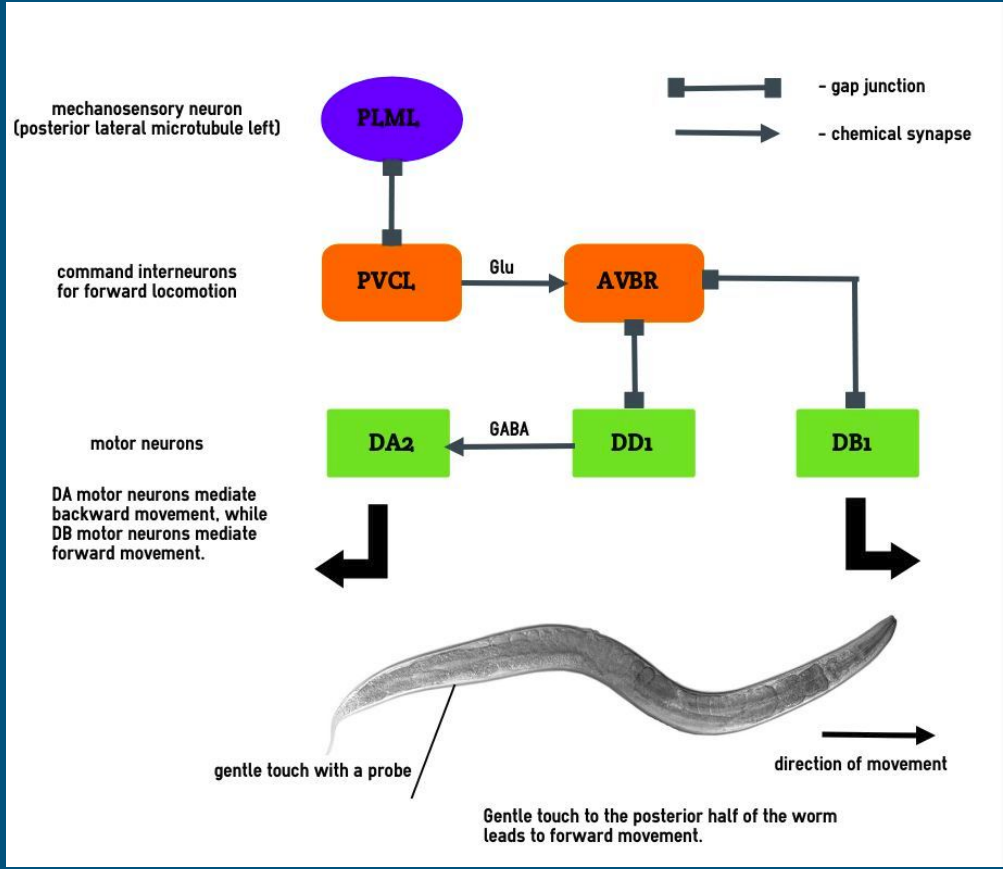
- A subset of this circuit is chosen for simulation.
- This subset links touch that is applied to the posterior half of the worm to forward movement of the animal (see the following slide).



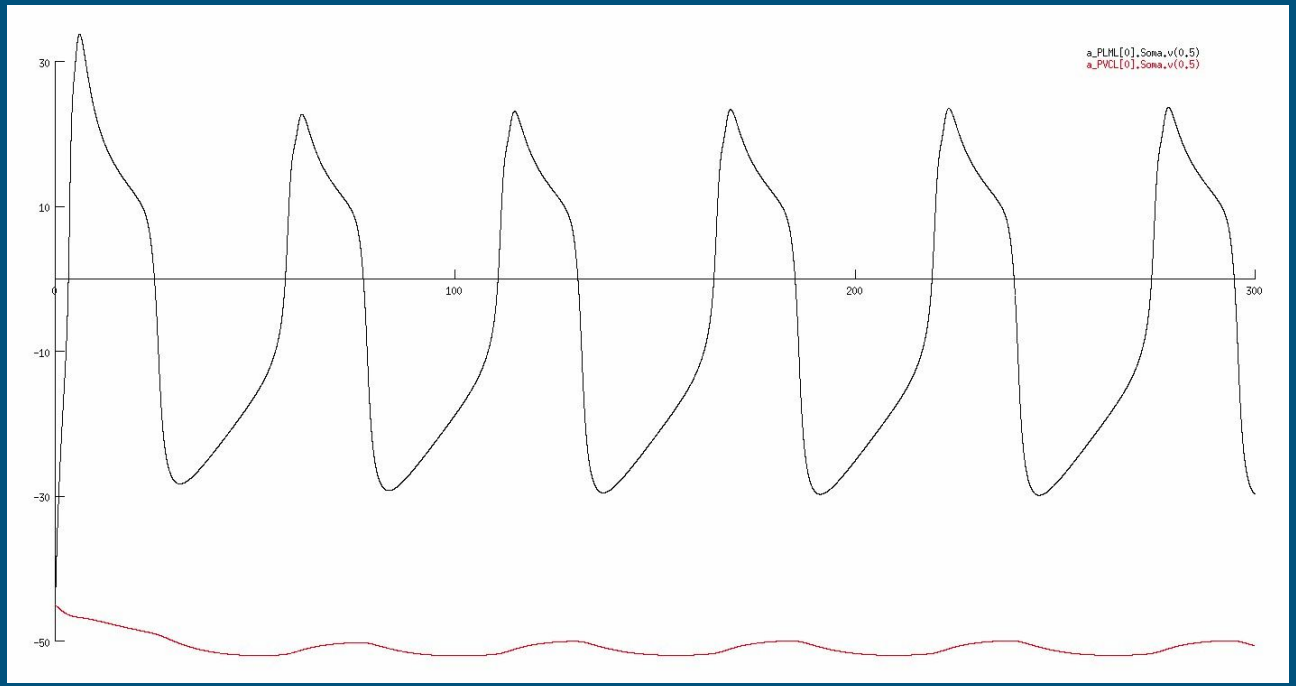
- source: Mechanosensation* Miriam B. Goodman§, Department of Molecular and Cellular Physiology,School of Medicine-Stanford University, Stanford, CA 94305-5345 USA

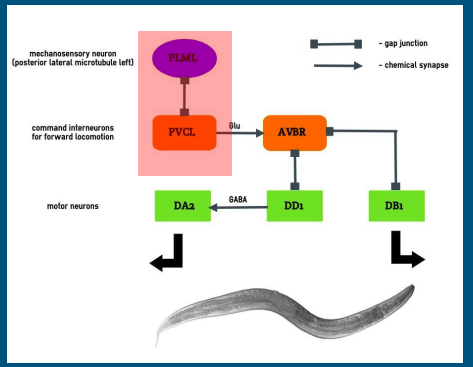
Possible subset to simulate

- advantages of this network
  - complete path from sensory input to motor neurons
  - both excitatory and inhibitory chemical synapses
  - several gap junctions



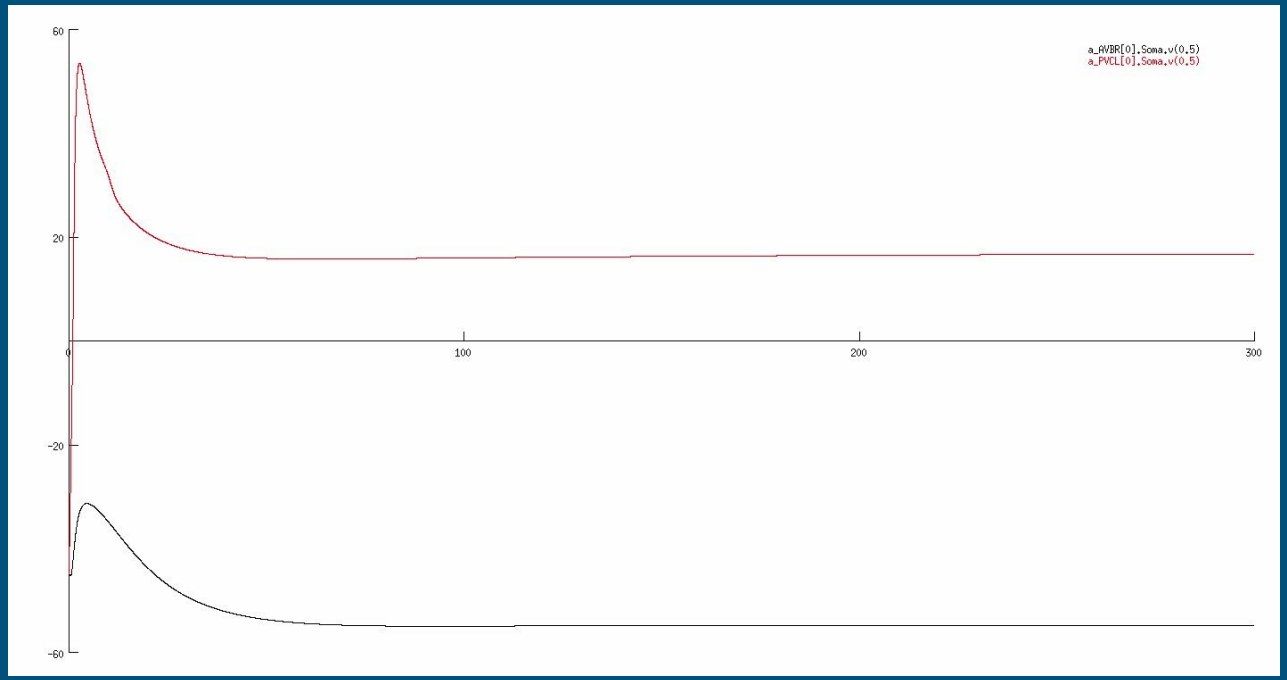
NEURON simulation: Gap junction PLML - PVCL

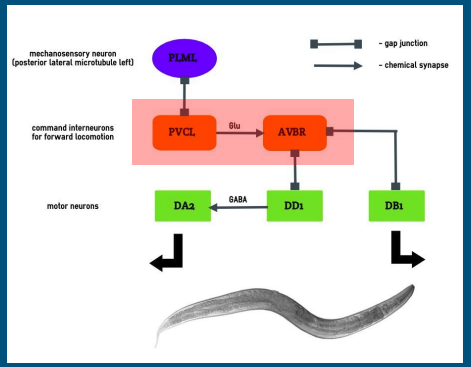




← membrane potential of PLML (black) (offset current: 8.7 pA) and PVCL (red)

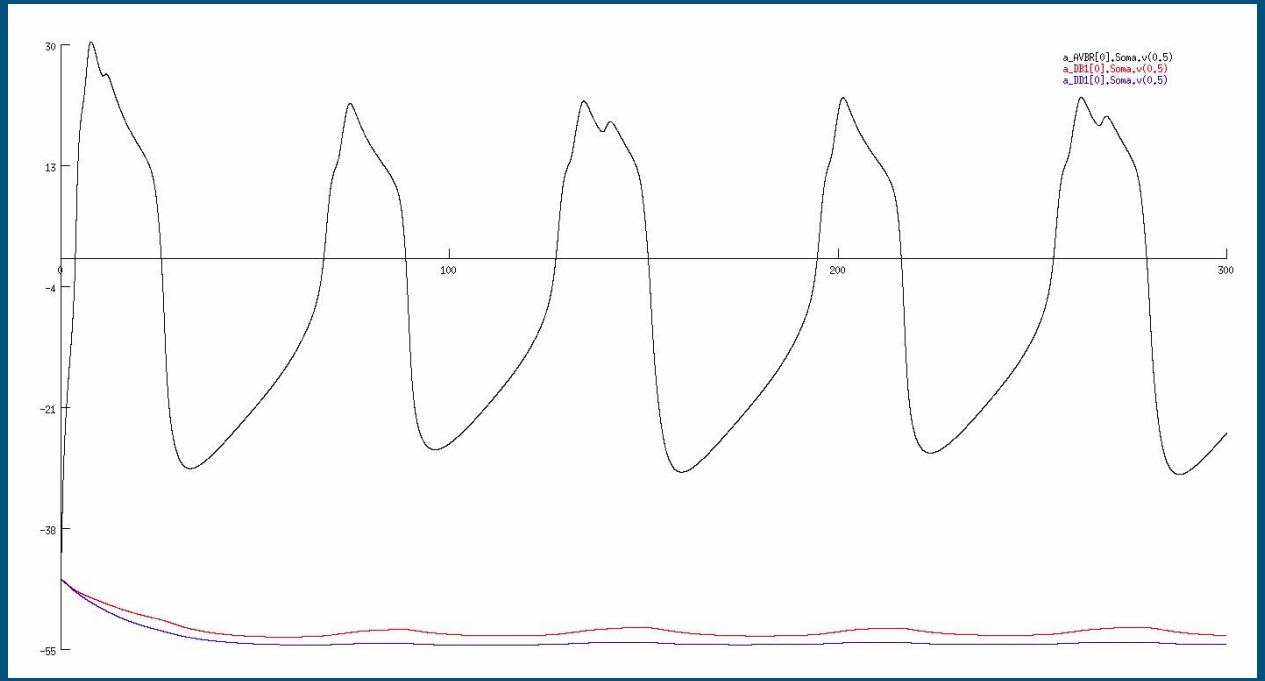
NEURON simulation: Synapse PVCL → AVBR (excitatory)

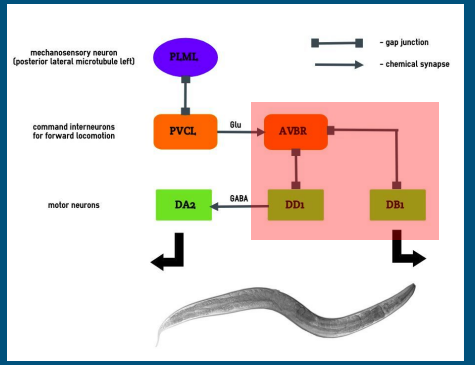




← membrane potential of PVCL (red) (offset current: 8.7 pA) and AVBR (black)

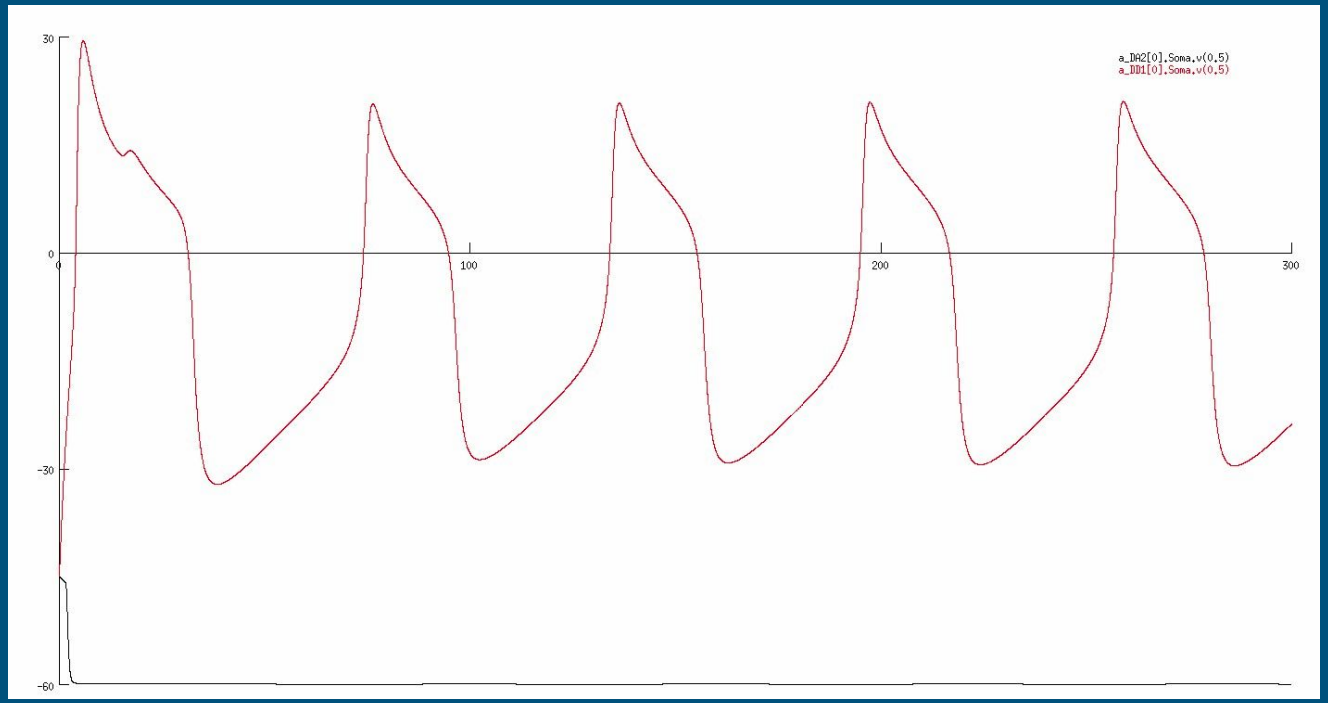
NEURON simulation: Gap junctions AVBR-DD1 and AVBR-DB1

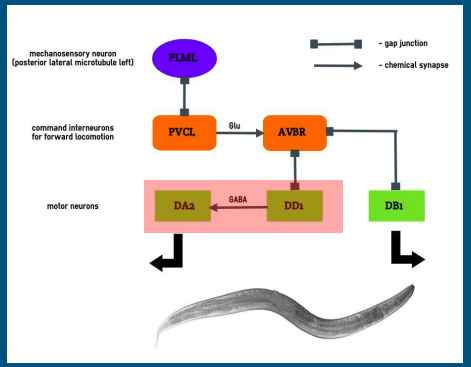




← membrane potential of AVBR (black) (offset current: 8.7 pA), DB1 (red) and DD1 (blue)

NEURON simulation: Synapse DD1 → DA2 (inhibitory)





← membrane potential of DD1 (red) (offset current: 8.7 pA) and DA1 (black)

Steps towards porting the identified circuit to Arbor

- use information from LEMS files

```
<!-- Include core NeuroML2 ComponentType definitions -->

<Include file="Cells.xml" />
<Include file="Networks.xml" />
<Include file="Simulation.xml" />

<Include file="cell_C.xml" />

<Include file="cells/PLML_D.cell.nml" />

<Include file="cells/PVCL_D.cell.nml" />

<Include file="PLML_PVCL_8_7.net.nml" />

<!-- End of NeuroML2 content -->


<Simulation id="sim_PLML_PVCL_8_7" length="300.0ms" step="0.01ms" target="PLML_PVCL_8_7">

    <Display id="neurons" title="PLML_PVCL_8_7: Membrane potential of a number of neurons" timeScale="1ms" xmin="-30.0" xmax="330.0" ymin="-80" ymax="-40">

        <Line id="PLML" quantity="PLML/0/PLML/v" scale="1mV" color="#f87100" timeScale="1ms" />
        <Line id="PVCL" quantity="PVCL/0/PVCL/v" scale="1mV" color="#ac15c4" timeScale="1ms" />

    </Display>
```

Steps towards porting the identified circuit to Arbor

- use information from net.nml files (NeuroML) → network structure

```xml
</notes>
    <include href="cell_C.xml"/>
    <include href="cells/PLML_D.cell.nml"/>
    <include href="cells/PVCL_D.cell.nml"/>
    <fixedFactorConcentrationModel id="CaPool" ion="ca" restingConc="0 mM" decayConstant="11.5943 ms" rho="0.000238919 mol_per_m_per_A_per_s"/>
    <gapJunction id="neuron_to_neuron_elec_syn" conductance="0.0005 nS"/>
    <cell id="GenericMuscleCell">
        <morphology id="morphology_GenericMuscleCell">
            &lt;segment id="0" name="soma"&gt;
                <proximal x="0.000000e+00" y="0.000000e+00" z="0.000000e+00" diameter="5.0"/>
                <distal x="0.000000e+00" y="2.000000e+01" z="0.000000e+00" diameter="5.0"/>
            &lt;/segment&gt;
        </morphology>
        <biophysicalProperties id="biophys_GenericMuscleCell">
            <membraneProperties>
                <channelDensity id="Leak_all" ionChannel="Leak" condDensity="0.005 mS_per_cm2" erev="-50 mV" ion="non_specific"/>
                <channelDensity id="k_slow_all" ionChannel="k_slow" condDensity="4 mS_per_cm2" erev="-60 mV" ion="k"/>
                <channelDensity id="k_fast_all" ionChannel="k_fast" condDensity="0.2 mS_per_cm2" erev="-60 mV" ion="k"/>
                <channelDensity id="ca_boyle_all" ionChannel="ca_boyle" condDensity="2 mS_per_cm2" erev="40 mV" ion="ca"/>
                <spikeThresh value="-26 mV"/>
                <specificCapacitance value="1 uF_per_cm2"/>
                <initMembPotential value="-45 mV"/>
            </membraneProperties>
            <intracellularProperties>
                <species id="ca" concentrationModel="CaPool" ion="ca" initialConcentration="0 mM" initialExtConcentration="2E-6 mol_per_cm3"/>
                <resistivity value="12 kohm_cm"/>
            </intracellularProperties>
        </biophysicalProperties>
    </cell>
    <pulseGenerator id="offset_current" delay="0 ms" duration="2000 ms" amplitude="8.7pA"/>
    <network id="PLML_PVCL_8_7">
```

Steps towards porting the identified circuit to Arbor

- use information from cell.nml files (NeuroML) → cell morphology and dynamics

<neuroml xmlns="http://www.neuroml.org/schema/neuroml2" xmlns:xs="http://www.w3.org/2001/XMLSchema" xmlns
ation="http://www.neuroml.org/schema/neuroml2 https://raw.github.com/NeuroML/NeuroML2/development/Schemas/
<cell id="PLML">
<notes>Cell model created by c302 with custom electrical parameters</notes>
<morphology id="morphology_PLML">
<segment id="0" name="Seg0_soma_0">
<proximal x="2.500000e+00" y="4.101500e+02" z="8.175000e+00" diameter="2.823119"/>
<distal x="2.500000e+00" y="4.101500e+02" z="8.175000e+00" diameter="2.823119"/>
</segment>
<segment id="7" name="Seg0_axon_0">
<parent segment="0"/>
<proximal x="2.500000e+00" y="4.101500e+02" z="8.175000e+00" diameter="0.53851646"/>
<distal x="2.500000e+00" y="4.092000e+02" z="7.850000e+00" diameter="0.53851646"/>
</segment>
<segment id="8" name="Seg8_axon_0">
<parent segment="7"/>
<distal x="3.050000e+00" y="4.070500e+02" z="7.250000e+00" diameter="0.4358899"/>
</segment>
<segment id="9" name="Seg9_axon_0">
<parent segment="8"/>
<distal x="1.155000e+01" y="3.874500e+02" z="2.600000e+00" diameter="0.50990194"/>
</segment>