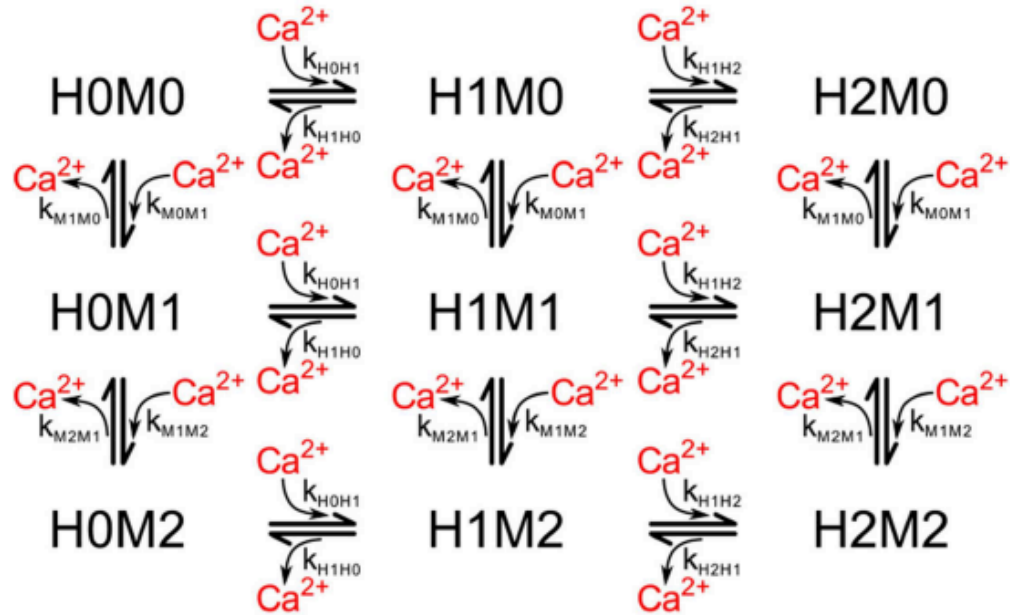


Detailed Markov Model

Calbindin



Calbindin-D28k

- ✓ calbindin_h0m0 + ca <=> calbindin_h1m0
- ✓ calbindin_h1m0 + ca <=> calbindin_h2m0
- ✓ calbindin_h0m1 + ca <=> calbindin_h1m1
- ✓ calbindin_h1m1 + ca <=> calbindin_h2m1
- ✓ calbindin_h0m2 + ca <=> calbindin_h1m2
- ✓ calbindin_h1m2 + ca <=> calbindin_h2m2
- ✓ calbindin_h0m0 + ca <=> calbindin_h0m1
- ✓ calbindin_h0m1 + ca <=> calbindin_h0m2
- ✓ calbindin_h1m0 + ca <=> calbindin_h1m1
- ✓ calbindin_h1m1 + ca <=> calbindin_h1m2
- ✓ calbindin_h2m0 + ca <=> calbindin_h2m1
- ✓ calbindin_h2m1 + ca <=> calbindin_h2m2

$$k_0 = k_{M0M1} = 17.4e7 \text{ M/s}$$

$$k_1 = k_{M1M2} = 8.7e7 \text{ M/s}$$

$$k_2 = k_{M1M0} = 35.8 \text{ 1/s}$$

$$k_3 = k_{M2M1} = 71.6 \text{ 1/s}$$

$$k_4 = k_{H0H1} = 2.2e7 \text{ M/s}$$

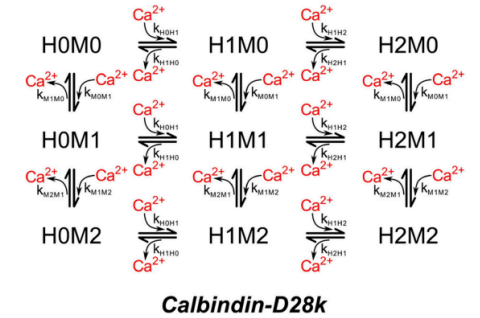
$$k_5 = k_{H1H2} = 1.1e7 \text{ M/s}$$

$$k_6 = k_{H1H0} = 2.6 \text{ 1/s}$$

$$k_7 = k_{H2H1} = 5.2 \text{ 1/s}$$

$$\frac{M}{s} = \frac{\text{mol}}{L \cdot s} \rightarrow \text{vol}(L) \cdot 6.022e23 \frac{1}{\text{mol}} \cdot \frac{\text{mol}}{L \cdot s} = \frac{\text{number}}{\text{sec}}$$

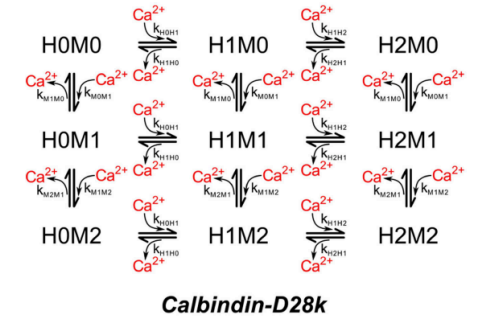
Calbindin Transitions



Transition Matrix

	H0M0	H0M1	H0M2	H1M0	H1M1	H1M2	H2M0	H2M1	H2M2
H0M0	$1 - \sum$	$k_0 N_{Ca} dt$	0	$k_4 N_{Ca} dt$	0	0	0	0	0
H0M1	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$	0	$k_4 N_{Ca} dt$	0	0	0	0
H0M2	0	$k_3 dt$	$1 - \sum$	0	0	$k_4 N_{Ca} dt$	0	0	0
H1M0	$k_6 dt$	0	0	$1 - \sum$	$k_0 N_{Ca} dt$	0	$k_5 N_{Ca} dt$	0	0
H1M1	0	$k_6 dt$	0	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$	0	$k_5 N_{Ca} dt$	0
H1M2	0	0	$k_6 dt$	0	$k_3 dt$	$1 - \sum$	0	0	$k_5 N_{Ca} dt$
H2M0	0	0	0	$k_7 dt$	0	0	$1 - \sum$	$k_0 N_{Ca} dt$	0
H2M1	0	0	0	0	$k_7 dt$	0	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$
H2M2	0	0	0	0	0	$k_7 dt$	0	$k_3 dt$	$1 - \sum$

Calbindin Transitions



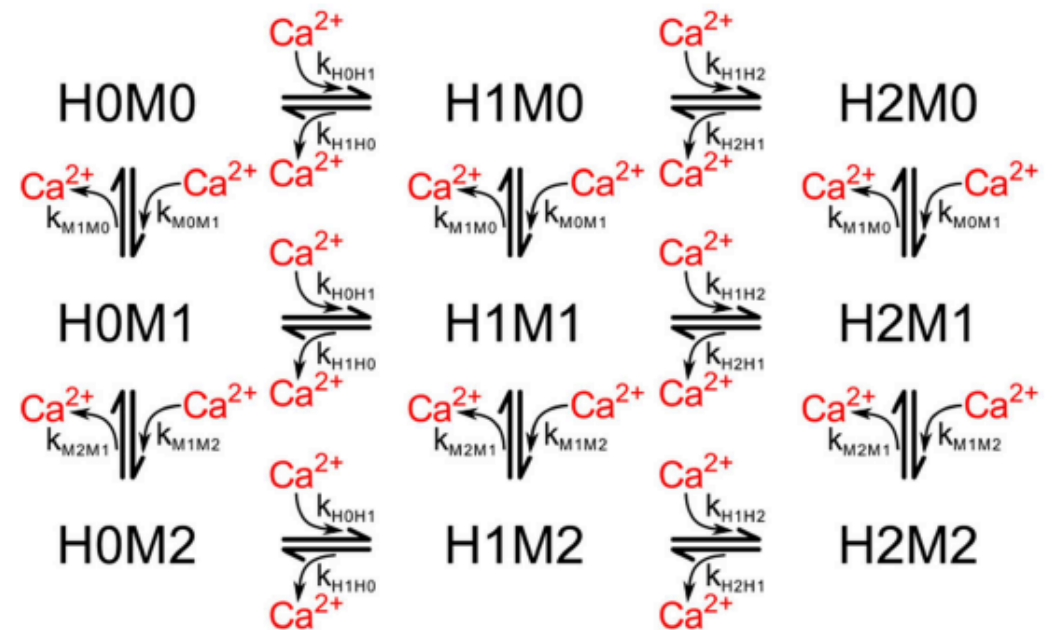
Transition Matrix

	S0	S1	S2	S3	S4	S5	S6	S7	S8
S0	$1 - \sum$	$k_0 N_{Ca} dt$	0	$k_4 N_{Ca} dt$	0	0	0	0	0
S1	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$	0	$k_4 N_{Ca} dt$	0	0	0	0
S2	0	$k_3 dt$	$1 - \sum$	0	0	$k_4 N_{Ca} dt$	0	0	0
S3	$k_6 dt$	0	0	$1 - \sum$	$k_0 N_{Ca} dt$	0	$k_5 N_{Ca} dt$	0	0
S4	0	$k_6 dt$	0	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$	0	$k_5 N_{Ca} dt$	0
S5	0	0	$k_6 dt$	0	$k_3 dt$	$1 - \sum$	0	0	$k_5 N_{Ca} dt$
S6	0	0	0	$k_7 dt$	0	0	$1 - \sum$	$k_0 N_{Ca} dt$	0
S7	0	0	0	0	$k_7 dt$	0	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$
S8	0	0	0	0	0	$k_7 dt$	0	$k_3 dt$	$1 - \sum$

Calbindin Transitions

- Transition affect the number of calcium due to binding and unbinding

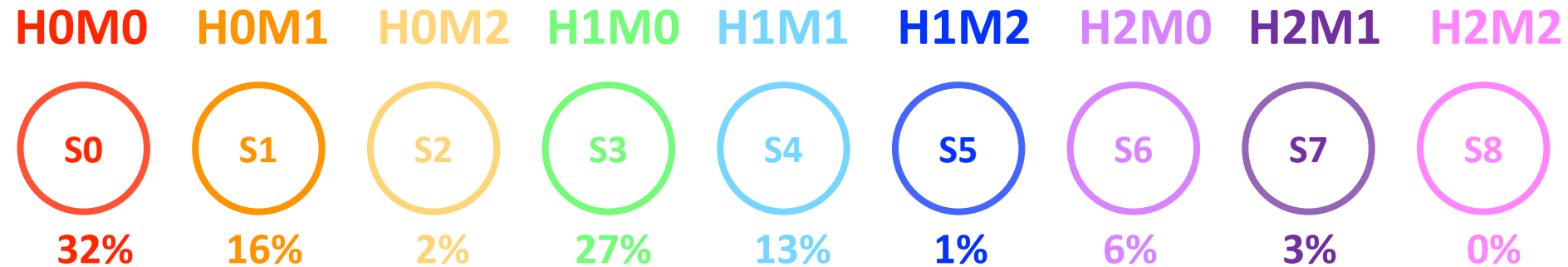
	00	01	02	10	11	12	20	21	22
00	0	-	0	-	0	0	0	0	0
01	+	0	-	0	-	0	0	0	0
02	0	+	0	0	0	-	0	0	0
10	+	0	0	0	-	0	-	0	0
11	0	+	0	+	0	-	0	-	0
12	0	0	+	0	+	0	0	0	-
20	0	0	0	+	0	0	0	-	0
21	0	0	0	0	+	0	+	0	-
22	0	0	0	0	0	+	0	+	0



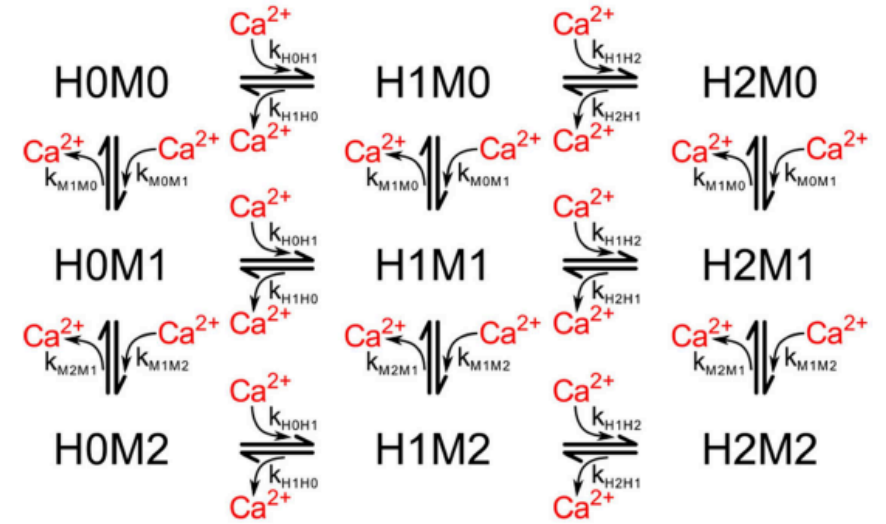
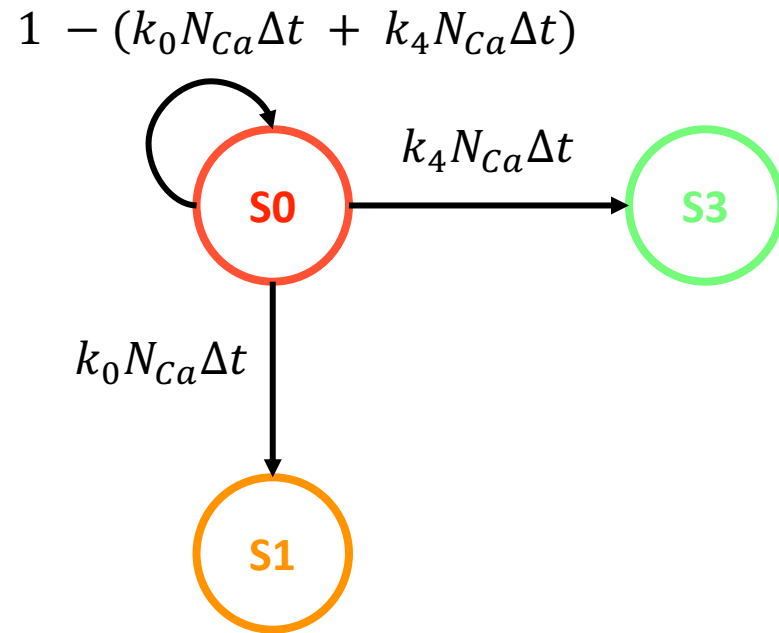
Calbindin-D28k

Calbindin Markov

- N calbindin total = 21284 (taken from initial concentration)
- N calcium total = 5322 (baseline plus action potential average)



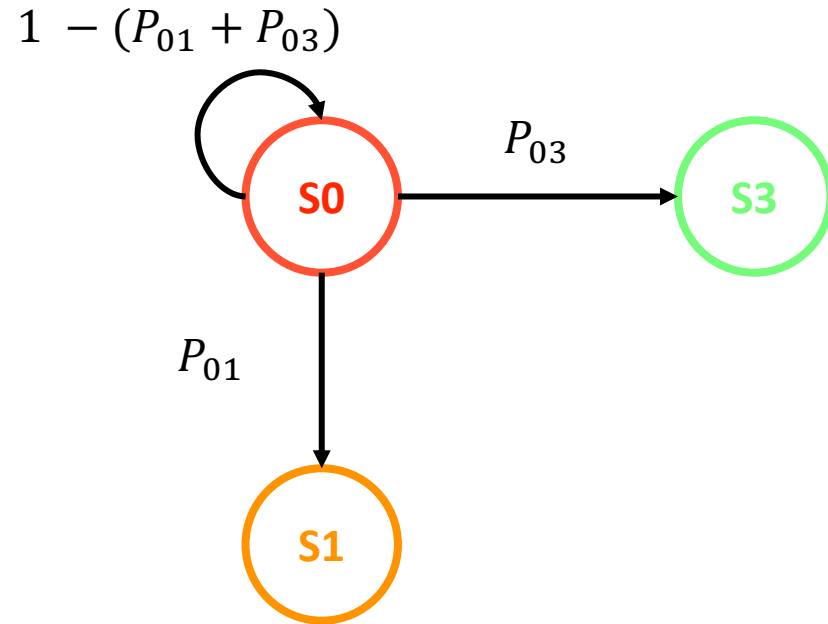
Calbindin Markov



Calbindin-D28k

	S0	S1	S2	S3	S4	S5	S6	S7	S8
S0	$1 - \sum$	$k_0 N_{Ca} dt$	0	$k_4 N_{Ca} dt$	0	0	0	0	0
S1	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$	0	$k_4 N_{Ca} dt$	0	0	0	0
S2	0	$k_3 dt$	$1 - \sum$	0	0	$k_4 N_{Ca} dt$	0	0	0
S3	$k_6 dt$	0	0	$1 - \sum$	$k_0 N_{Ca} dt$	0	$k_5 N_{Ca} dt$	0	0
S4	0	$k_6 dt$	0	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$	0	$k_5 N_{Ca} dt$	0
S5	0	0	$k_6 dt$	0	$k_3 dt$	$1 - \sum$	0	0	$k_5 N_{Ca} dt$
S6	0	0	0	$k_7 dt$	0	0	$1 - \sum$	$k_0 N_{Ca} dt$	0
S7	0	0	0	0	$k_7 dt$	0	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$
S8	0	0	0	0	0	$k_7 dt$	0	$k_3 dt$	$1 - \sum$

Calbindin Markov

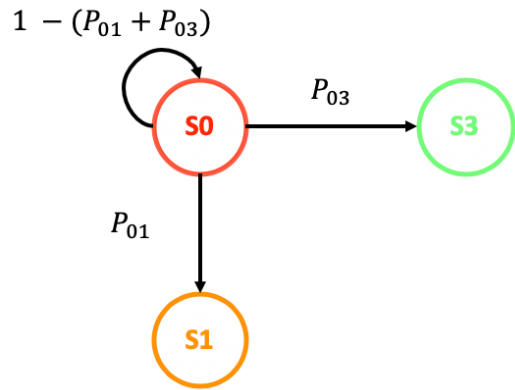


$$\begin{aligned}
 t_0 \quad & [\quad N_{0,t_0}, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0] \\
 & [1 - (P_{01} + P_{03}), \quad P_{01}, \quad 0, \quad P_{03}, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0]
 \end{aligned}$$

$$t_0 + \Delta t \quad [N_{0,t_0} - (N_1 + N_3), \quad N_1, \quad 0, \quad N_3, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0]$$

	S0	S1	S2	S3	S4	S5	S6	S7	S8
S0	$1 - \sum$	$k_0 N_{Ca} dt$	0	$k_4 N_{Ca} dt$	0	0	0	0	0
S1	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$	0	$k_4 N_{Ca} dt$	0	0	0	0
S2	0	$k_3 dt$	$1 - \sum$	0	0	$k_4 N_{Ca} dt$	0	0	0
S3	$k_6 dt$	0	0	$1 - \sum$	$k_0 N_{Ca} dt$	0	$k_5 N_{Ca} dt$	0	0
S4	0	$k_6 dt$	0	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$	0	$k_5 N_{Ca} dt$	0
S5	0	0	$k_6 dt$	0	$k_3 dt$	$1 - \sum$	0	0	$k_5 N_{Ca} dt$
S6	0	0	0	$k_7 dt$	0	0	$1 - \sum$	$k_0 N_{Ca} dt$	0
S7	0	0	0	0	$k_7 dt$	0	$k_2 dt$	$1 - \sum$	$k_1 N_{Ca} dt$
S8	0	0	0	0	0	$k_7 dt$	0	$k_3 dt$	$1 - \sum$

Calbindin Markov



$$\begin{aligned}
 t_0 \quad & [\quad N_{0,t_0}, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0] \\
 & [1 - (P_{01} + P_{03}), \quad P_{01}, \quad 0, \quad P_{03}, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0]
 \end{aligned}$$

$$t_0 + \Delta t \quad [N_{0,t_0} - (N_1 + N_3), \quad N_1, \quad 0, \quad N_3, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0]$$

x

$$\text{Calcium} \quad [\quad 0, \quad -1, \quad 0, \quad -1, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0]$$

$$\text{Calcium} \quad \sum [0, \quad -N_1, \quad 0, \quad -N_3, \quad 0, \quad 0, \quad 0, \quad 0, \quad 0] = -(N_1 + N_3)$$

$$\text{Calcium}(t_0 + \Delta t) = \text{Calcium}(t_0) - (N_1 + N_3)$$

$$\begin{bmatrix}
 0 & - & 0 & - & 0 & 0 & 0 & 0 & 0 \\
 + & 0 & - & 0 & - & 0 & 0 & 0 & 0 \\
 0 & + & 0 & 0 & 0 & - & 0 & 0 & 0 \\
 + & 0 & 0 & 0 & - & 0 & - & 0 & 0 \\
 0 & + & 0 & + & 0 & - & 0 & - & 0 \\
 0 & 0 & + & 0 & + & 0 & 0 & 0 & - \\
 0 & 0 & 0 & + & 0 & 0 & 0 & - & 0 \\
 0 & 0 & 0 & 0 & + & 0 & + & 0 & - \\
 0 & 0 & 0 & 0 & 0 & + & 0 & + & 0
 \end{bmatrix}$$