http://www.koraorganics.com/blog/live-in-my-skin/final-instalment-to-the-trilogy-of-carbs-fats-and-proteins/

# Module 2 overview

| *lecture* | *lab* |
|---|---|
| 1. Introduction to the module | 1. Start-up protein eng. |
| 2. Rational protein design | 2. Site-directed mutagenesis |
| 3. Fluorescence and sensors | 3. DNA amplification |
| 4. Protein expression | 4. Prepare expression system |
| **SPRING BREAK** | |
| 5. Review & gene analysis | 5. Induce protein |
| 6. Purification and protein analysis | 6. Purify protein |
| 7. Binding & affinity measurements | 7. Characterize expression |
| 8. High throughput engineering | 8. Assess protein function |

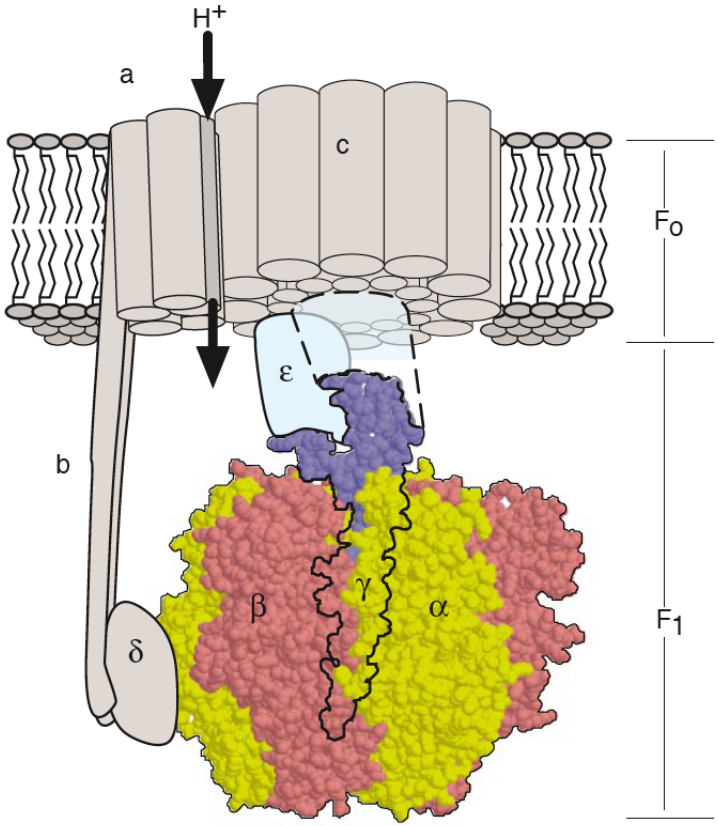
**Lecture 1: Introduction to the module**

I. Engineering proteins

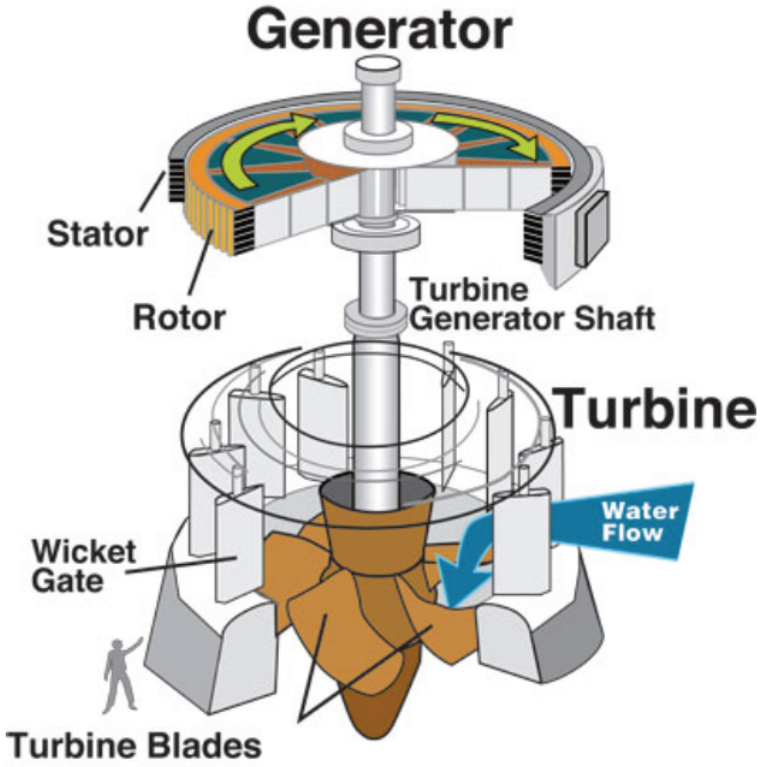
II. Pericam: an engineered protein sensor
   A. Imaging calcium signaling
   B. Calmodulin and GFP
   C. Pericam variants

III. Reengineering Pericam: experimental overview
   A. Structure-based design
   B. Protein expression and purification
   C. Measurements and analysis

# Proteins are machines!



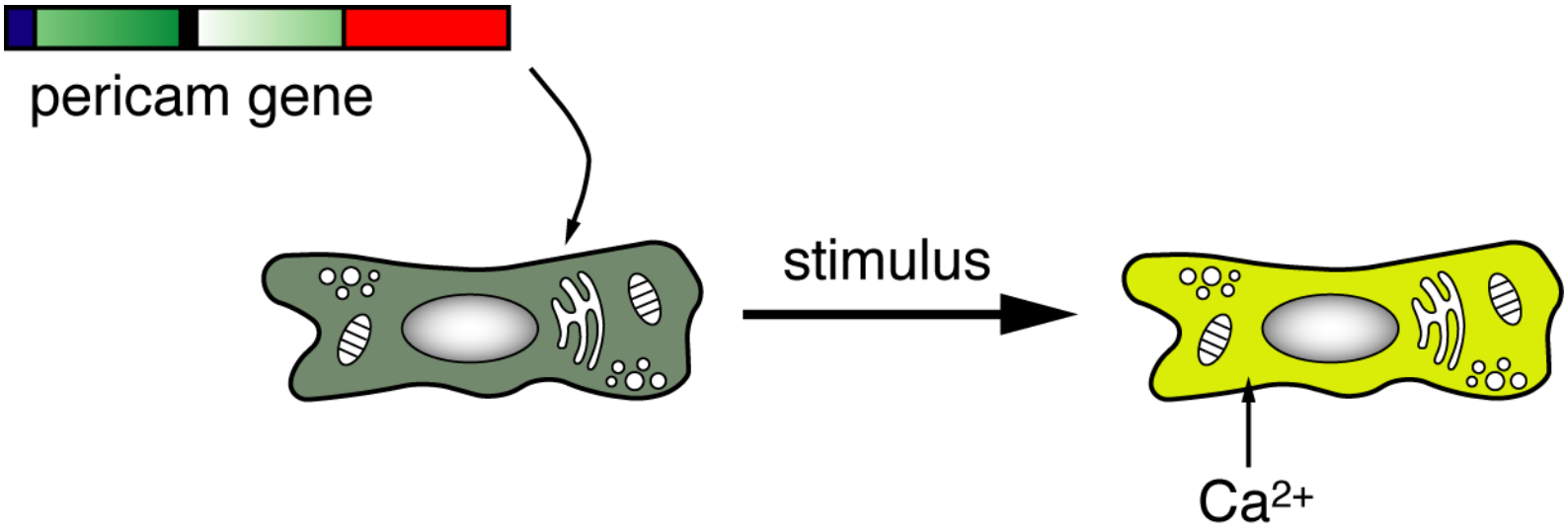

Wang & Oster (1998) *Nature 396:* 279-82



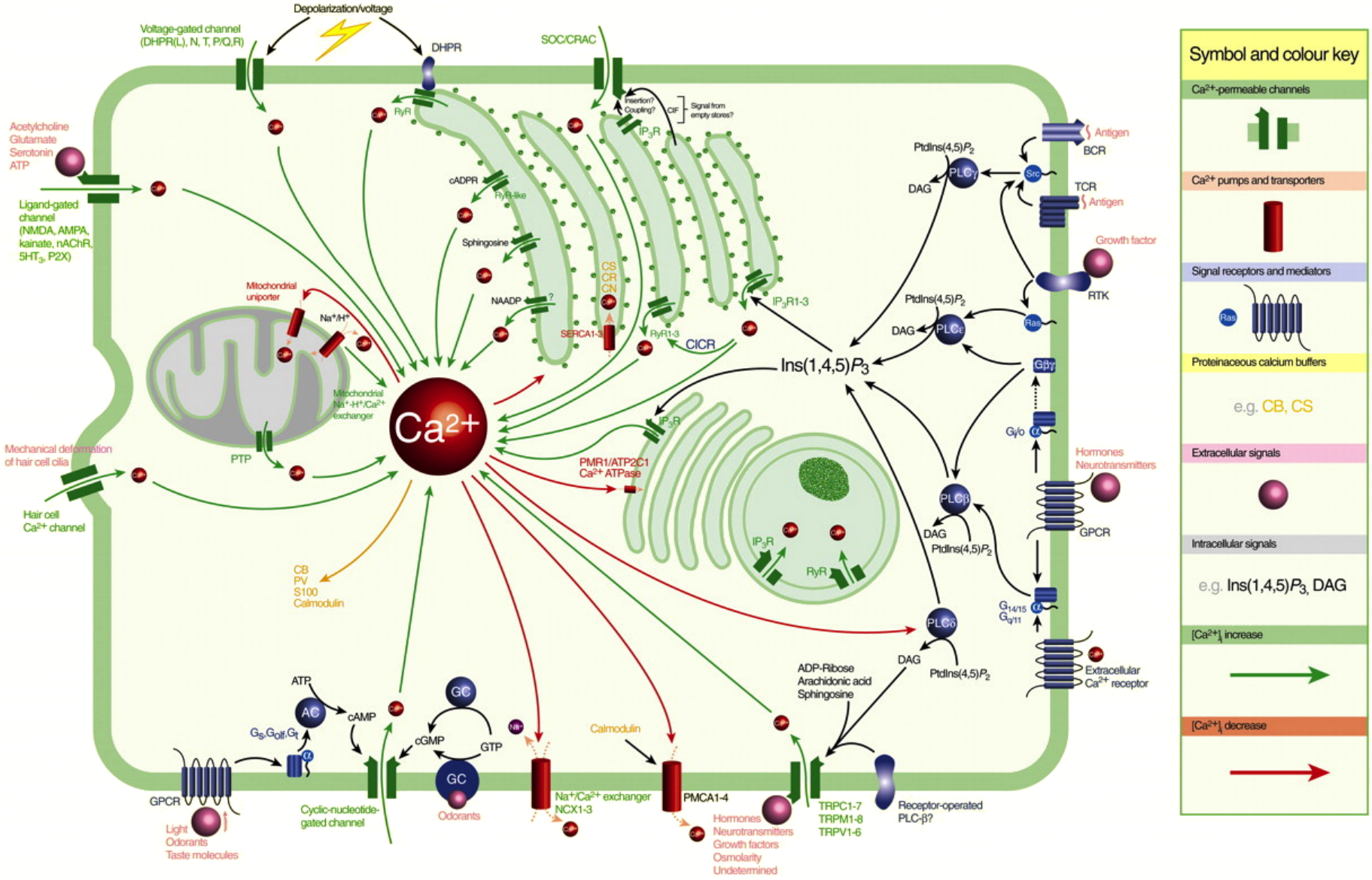

www.symscape.com/node/420

http://www.youtube.com/watch?v=PjdPTY1wHdQ

# Pericam: a protein-based machine for measuring [$Ca^{2+}$]



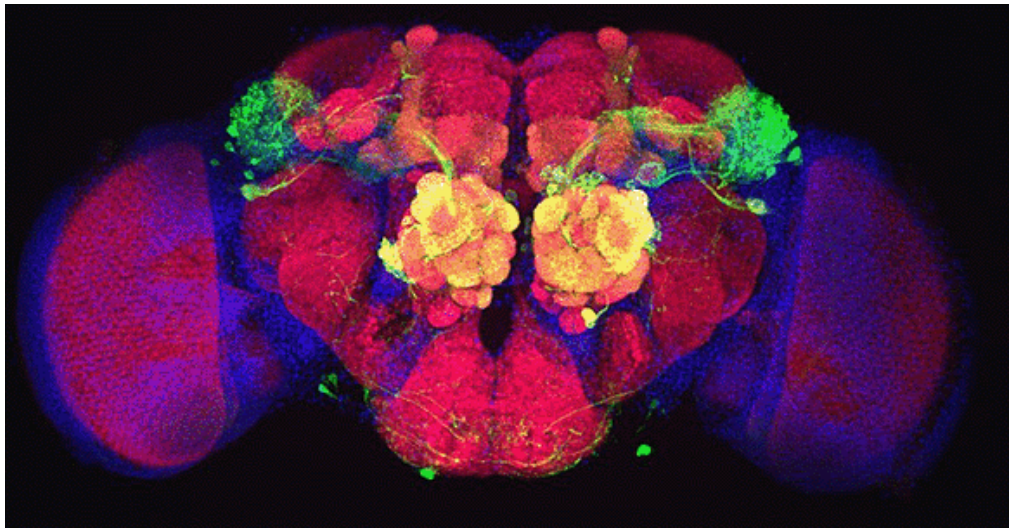

Nagai *et al.* (2001) *Proc. Natl. Acad. Sci. USA 98:* 3197-202



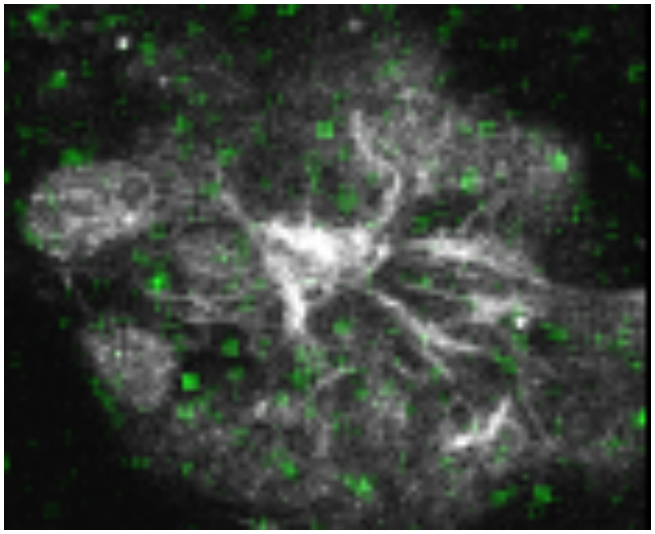

Nowycky *et al.* (2002) *J. Cell. Sci. 115:* 3715-3716

Calcium indicators can be used to detect signaling in individual cells and multicellular ensembles. Two purposes:

- learn what stimuli trigger calcium fluctuations and how calcium behaves in context of an organism or system
- use calcium as a “handle” on cell-cell interaction (*e.g.* neural activity)

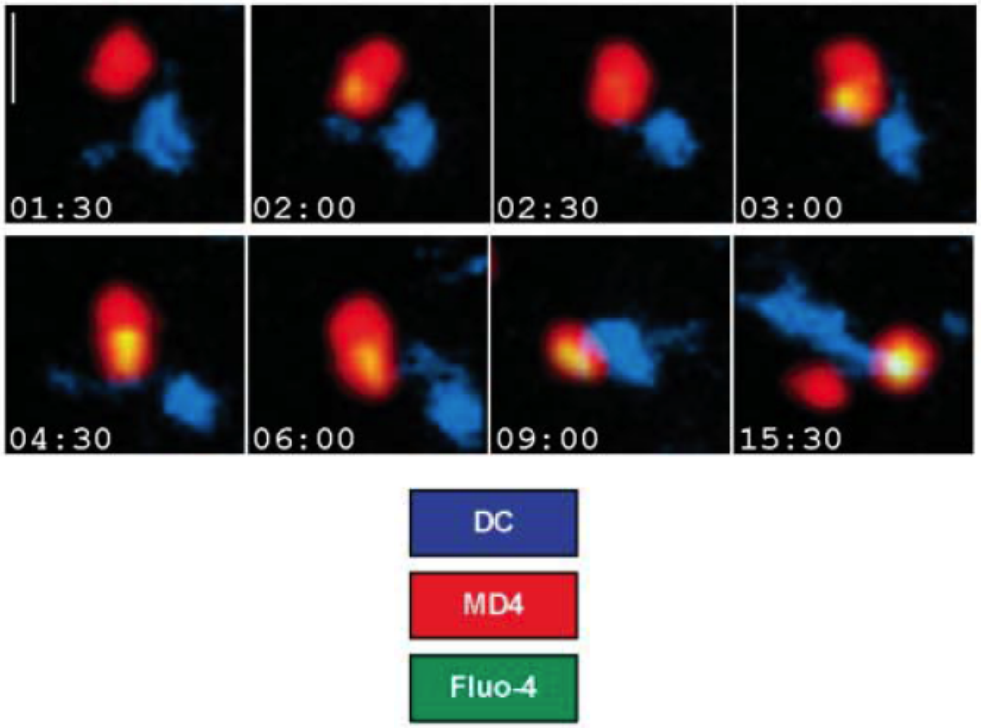


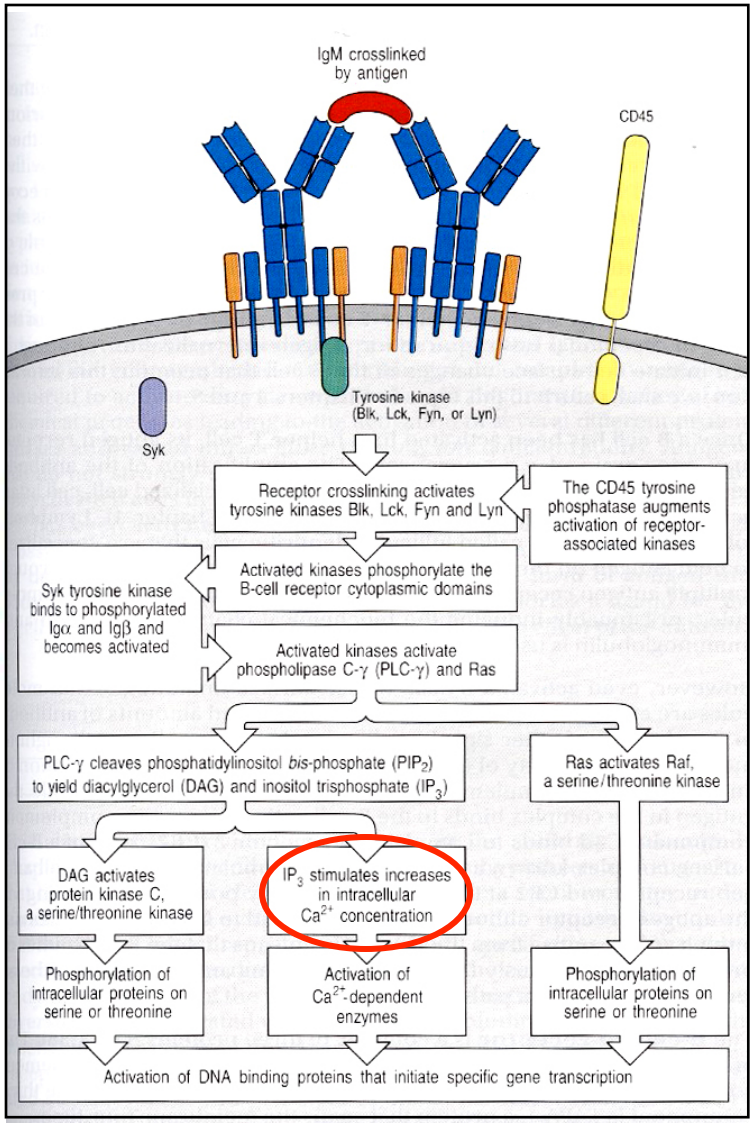
caproic acid stimulus

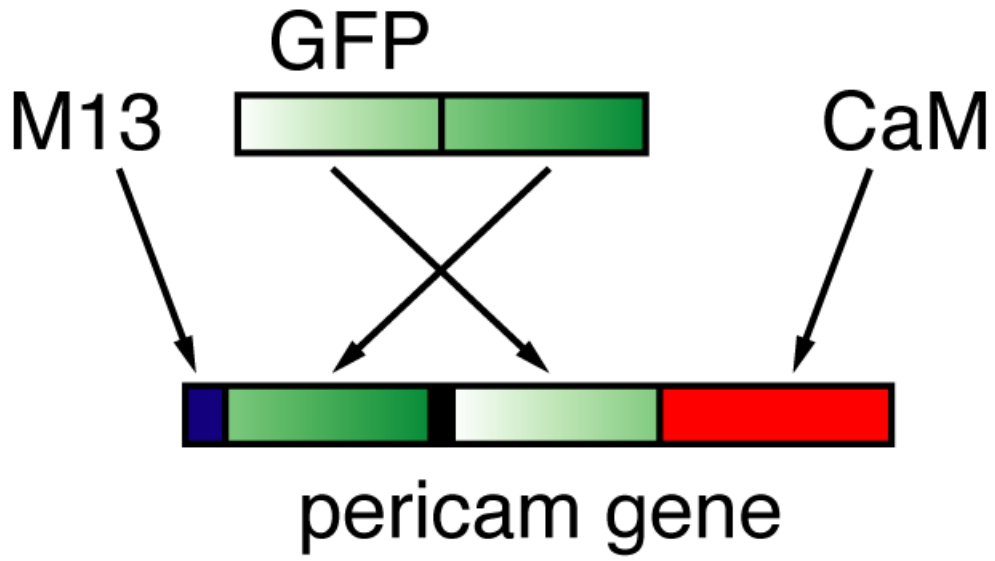


J. W. Wang *et al*. (2003) *Cell 112:* 271-82.

Calcium is important to cellular signaling in the immune system. Activation of B-cells can be detected by calcium imaging in lymph nodes (Qi *et al.*, 2006, *Science*).



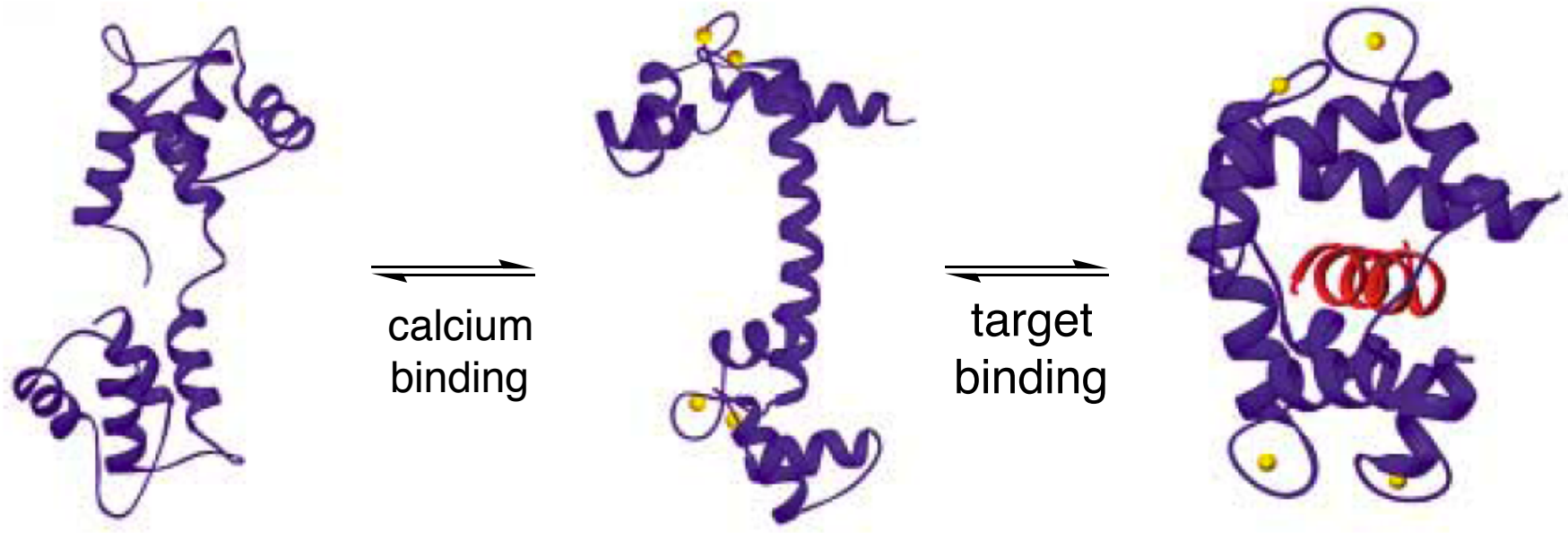



GFP = green fluorescent protein
CaM = calmodulin, a calcium-sensing protein
M13 is a CaM-binding fragment of a cellular kinase

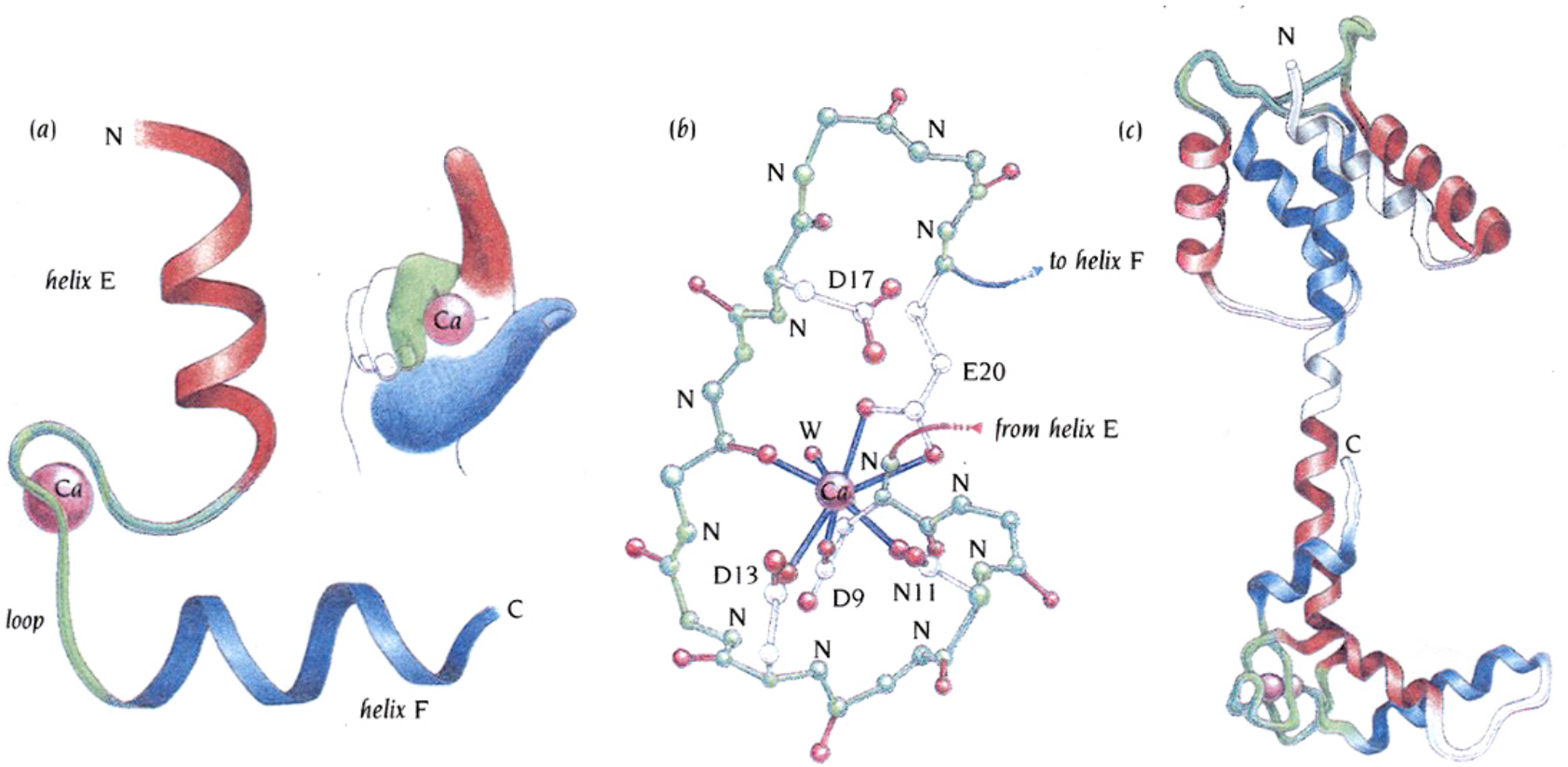
Pericam is a second generation calcium sensor, based on design strategies originally developed by Roger Tsien and colleagues. Tsien won a 2008 Nobel Prize for engineering novel forms of GFP.

## Calmodulin (CaM) facts and figures

- 16-18 kD (depending on species), ~20 x 40 Å protein
- highly conserved among eukaryotes (vertebrate and yeast calmodulin are functionally interchangeable)
- binds four $Ca^{2+}$ ions using EF hand amino acid sequence motifs
- $Ca^{2+}$-CaM binds short segments of target proteins, modulates activity



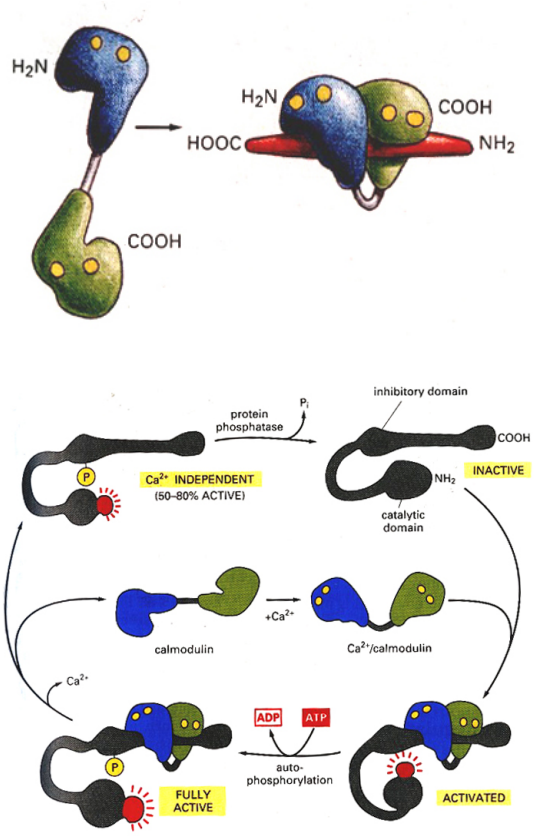

**apo-CaM** **$Ca^{2+}$/CaM** **$Ca^{2+}$/CaM-target**

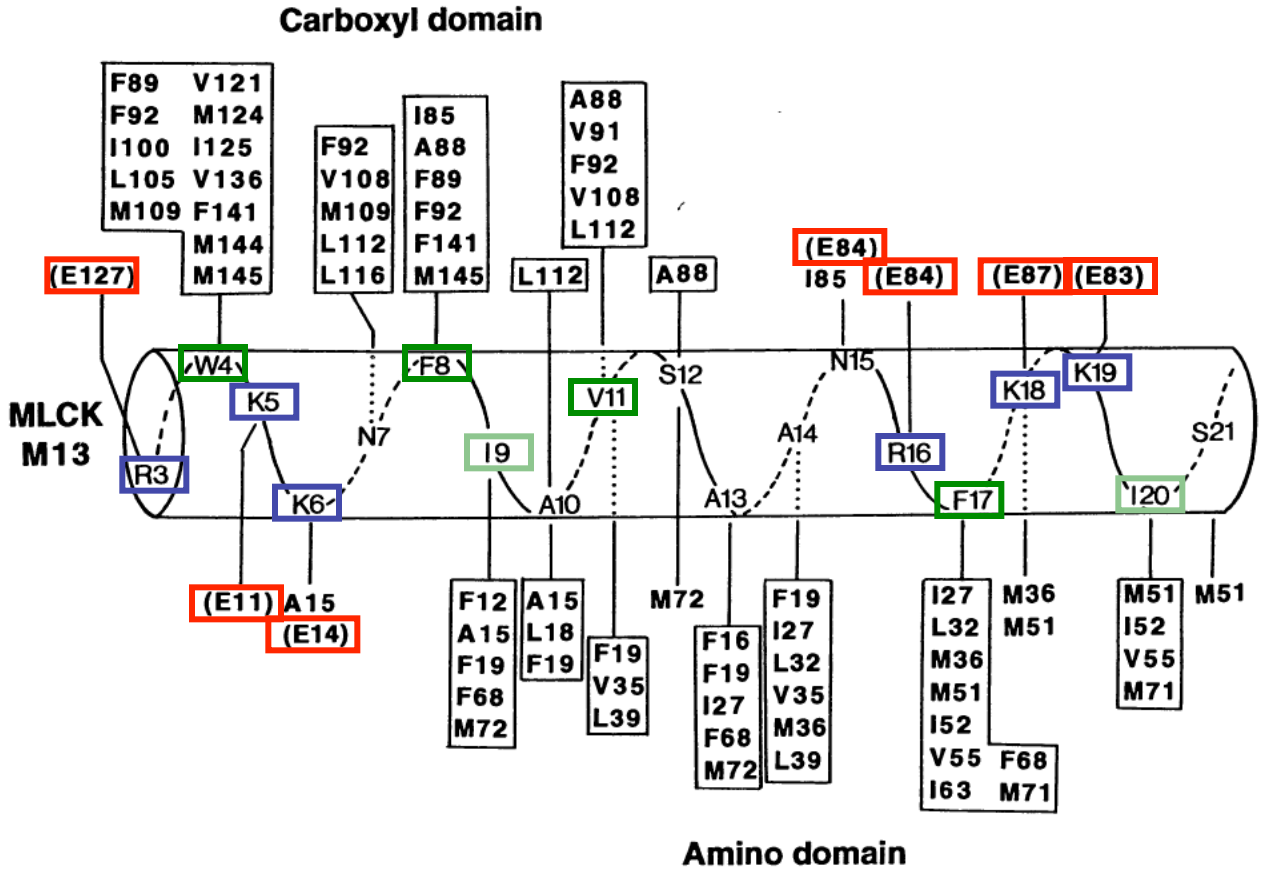



EF hand binding motif named for E & F helices of the calcium-binding protein parvalbumin; example of helix-loop-helix structure, with calcium bound in the loop

N- and C-terminal domains of CaM both contain two EF hand motifs

$Ca^{2+}$-saturated CaM binds to peptides by "grasping" target sequences, in helical conformation, between N- and C-terminal domains. In many cases, this activates an enzyme by sequestering an inhibitory domain (*e.g.* **M13** from MLCK). Interactions between CaM and targets involve hydrophobic contact area and charge-charge interactions.



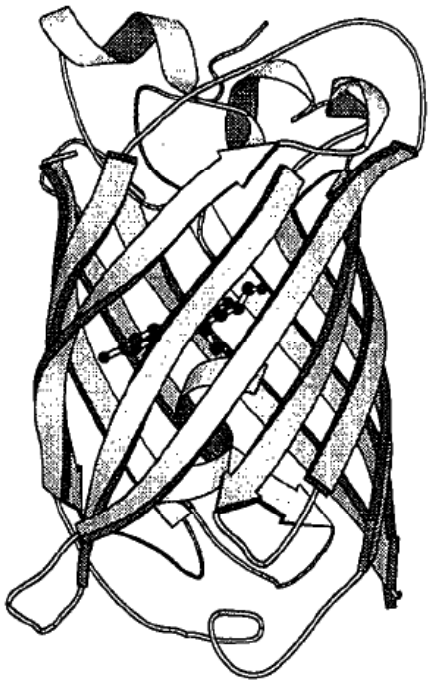

Ikura *et al.* (1992) *Science 256:* 632-8.

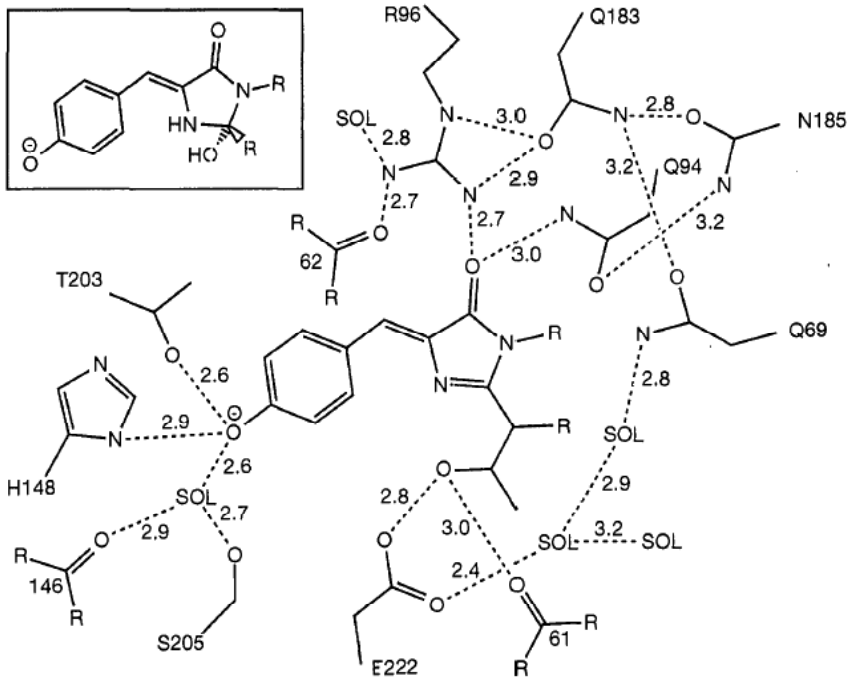
www.youtube.com

## Green Fluorescent Protein (GFP)

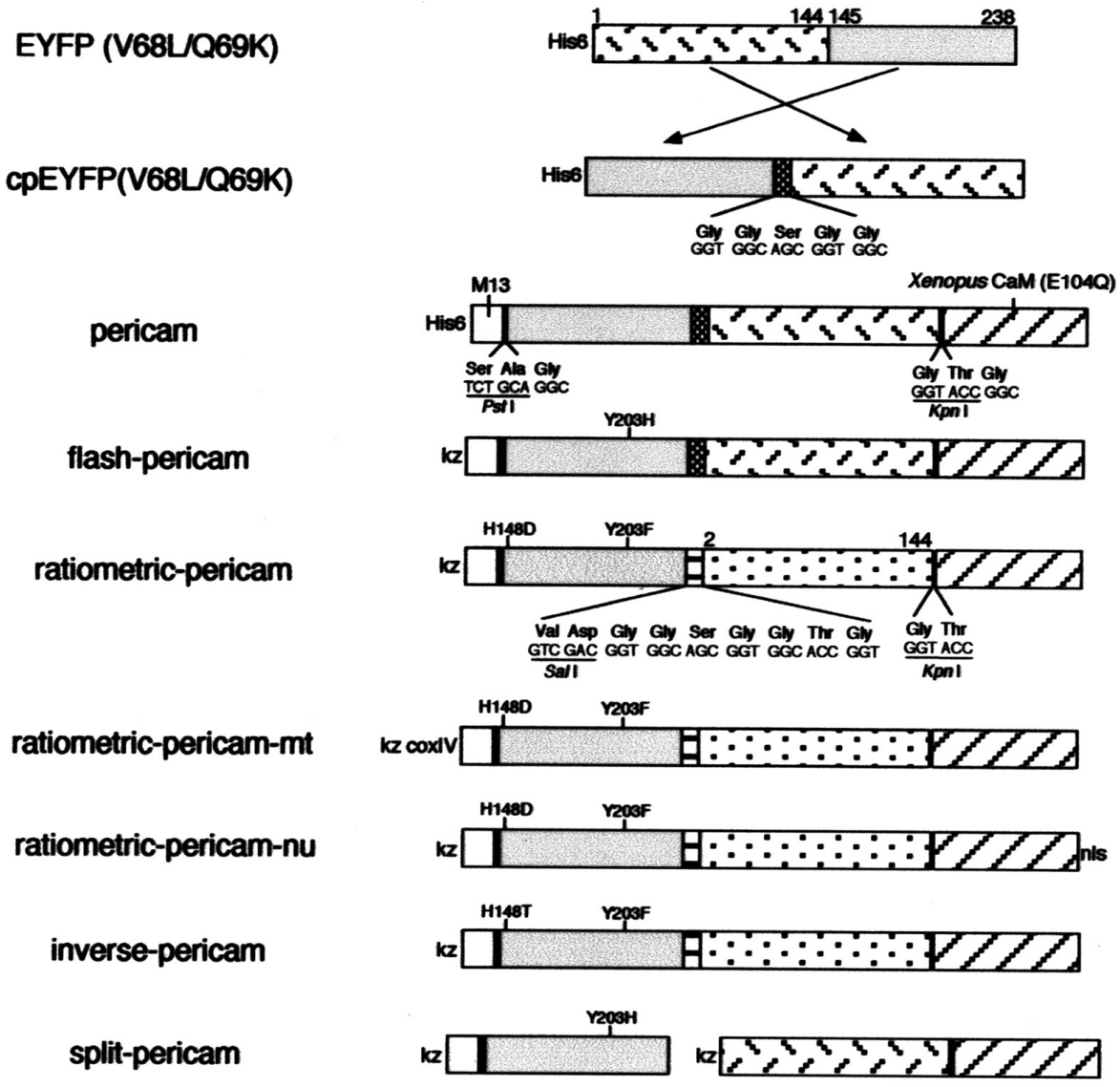


from the jellyfish *Aequoria victoria* is a protein fluorophore and component of genetically-encoded calcium indicators. The molecular structure (1996) shows a chromophore formed by spontaneous cyclization and oxidation of three amino acids (Ser/Thr65, Tyr66, and Gly67).






Ormo *et al.* (1996) *Science 273:* 1392-5.




**parent construct**

**dynamic range**

**ratiometric $\Delta F$**

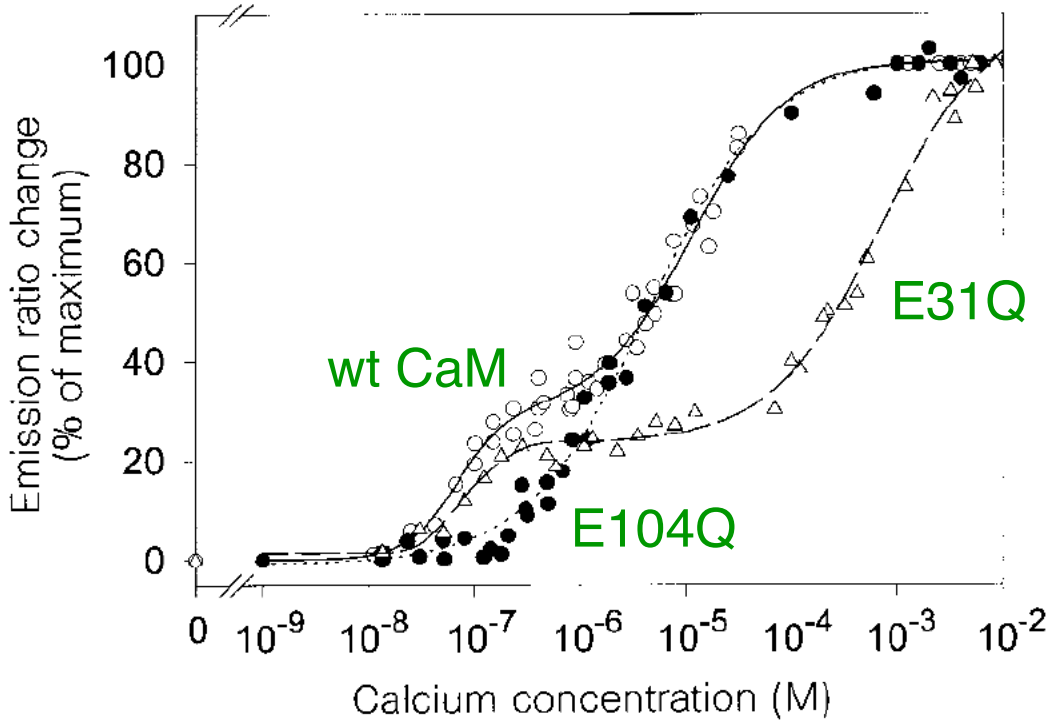
**mitoch. localization**

**nuclear localization**

**inverse $\Delta F$**

**fun**

Mutations can also affect calcium sensitivity; both $K_d$ (affinity) and cooperativity (slope/shape of transition) can be affected. Miyawaki *et al.* engineered calcium sensitivity of CaMeleons, a related type of engineered protein calcium sensor:

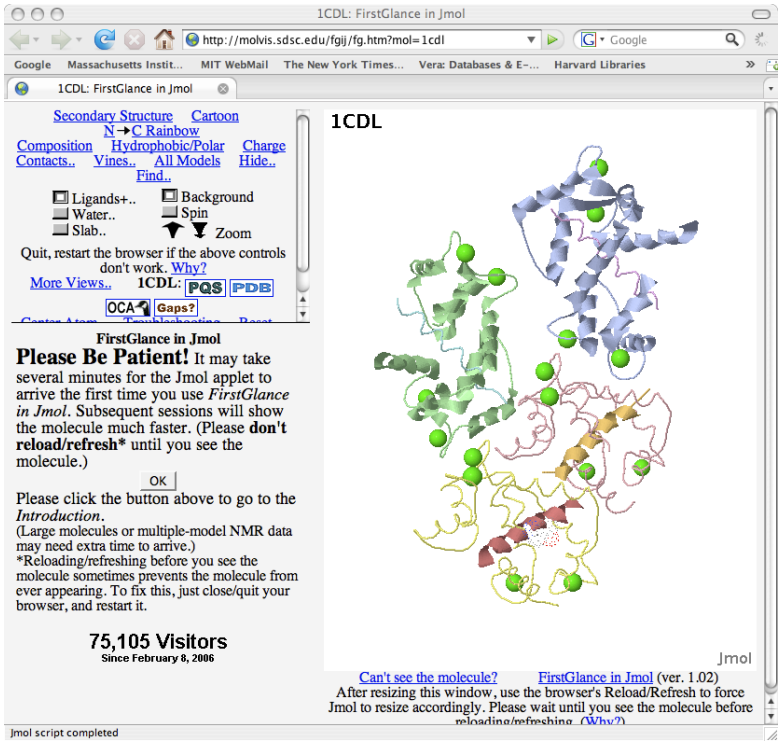


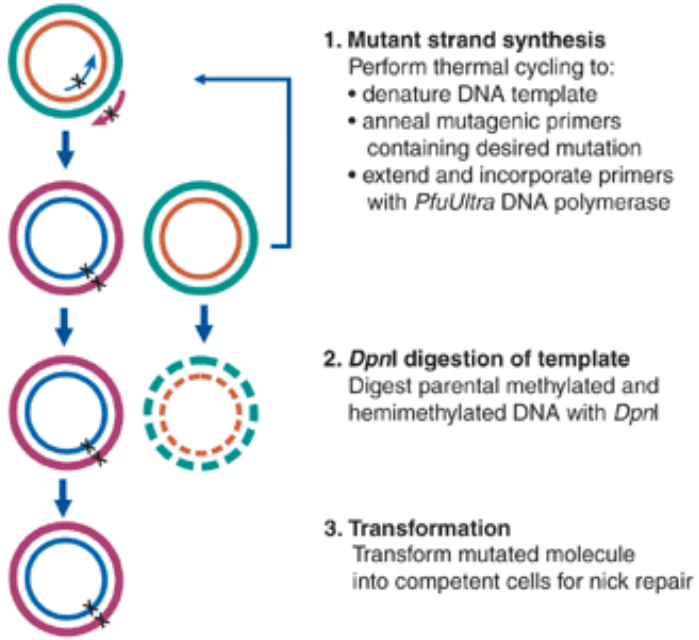

**In this module, our goal will be to influence the calcium sensitivity of "inverse pericam."**

**Step 1:** Design and implement mutations to affect inverse pericam's calcium sensitivity.

**Skills:**

- Use computational tool to look closely at protein structures
- Design primers to make site mutations in the pericam gene
- Perform mutagenesis using PCR

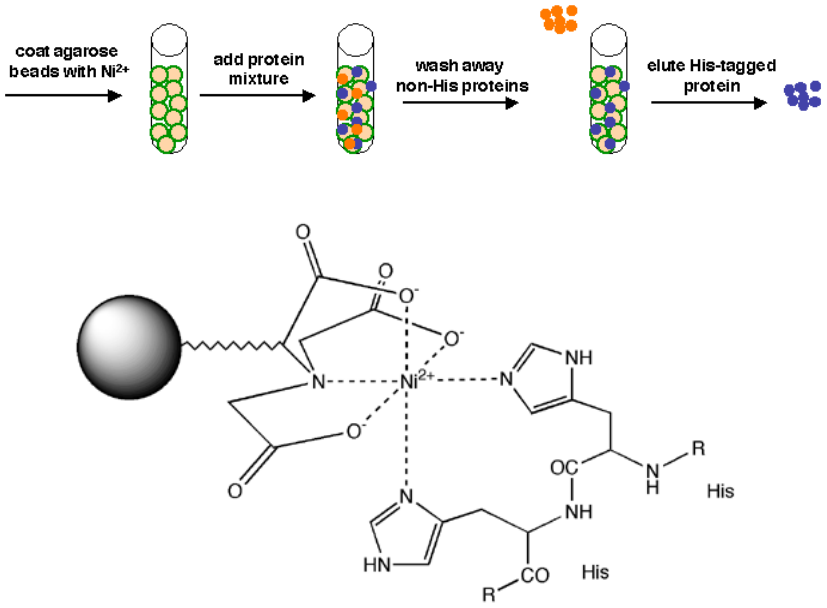


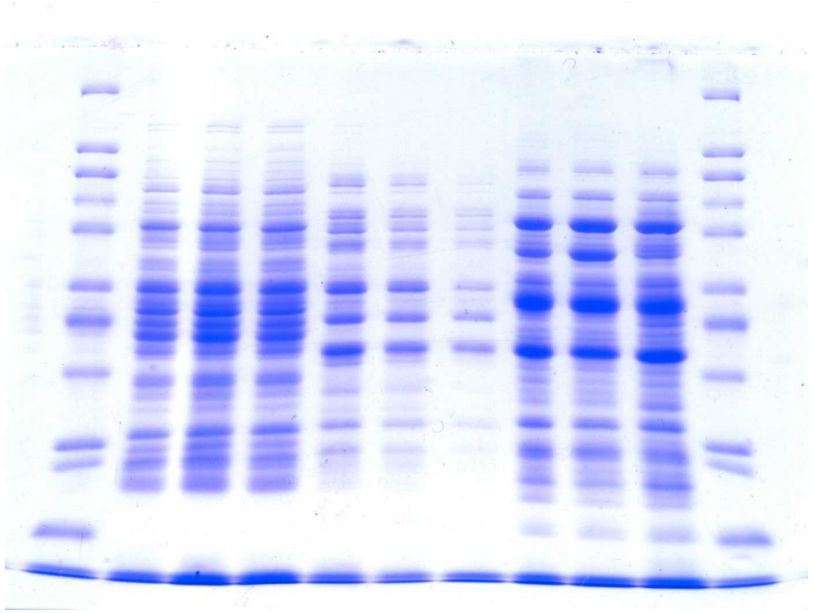



**Step 2:** Express and purify mutant inverse pericams for analysis.

**Skills:**

- Transform plasmid DNA into *E. coli*
- Induce protein expression using IPTG
- Purify mutant pericams using affinity-based separation
- Assay protein expression and purity using SDS-PAGE

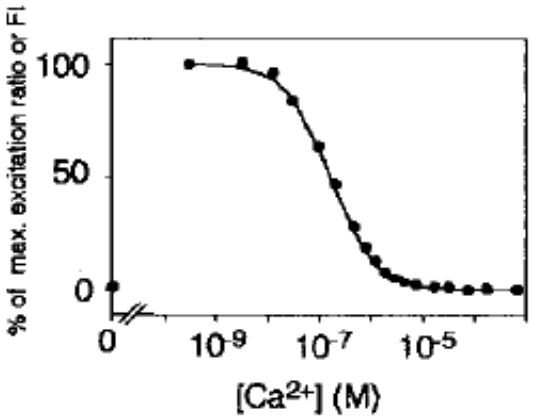


**Step 3:** Analyze calcium titration behavior of mutant pericams.

**Skills:**

- Perform fluorescence assays to measure calcium binding
- Use software to extract binding parameters from the data
- Pool data from across the class to observe patterns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*       **     * *     *
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