OCTOPUS APPLICATIONS IN BIOMEDICAL ENGINEERING

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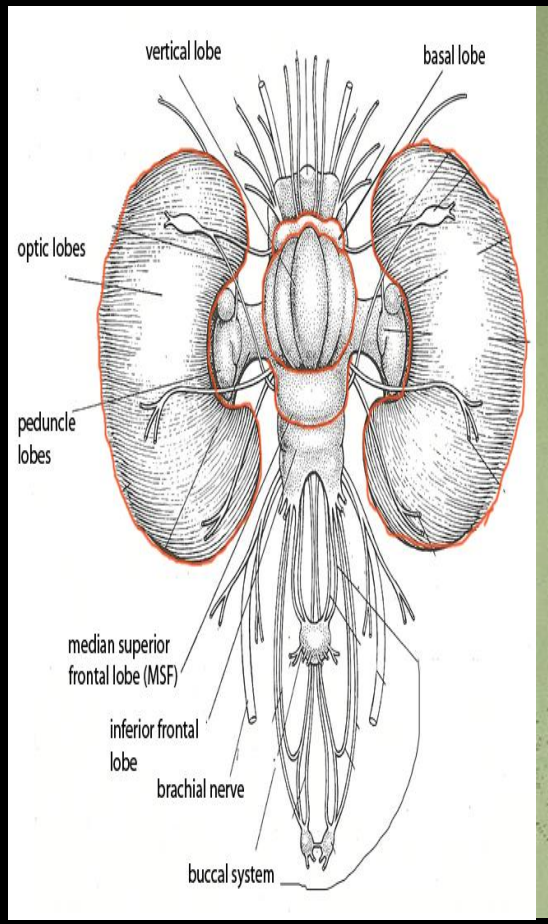
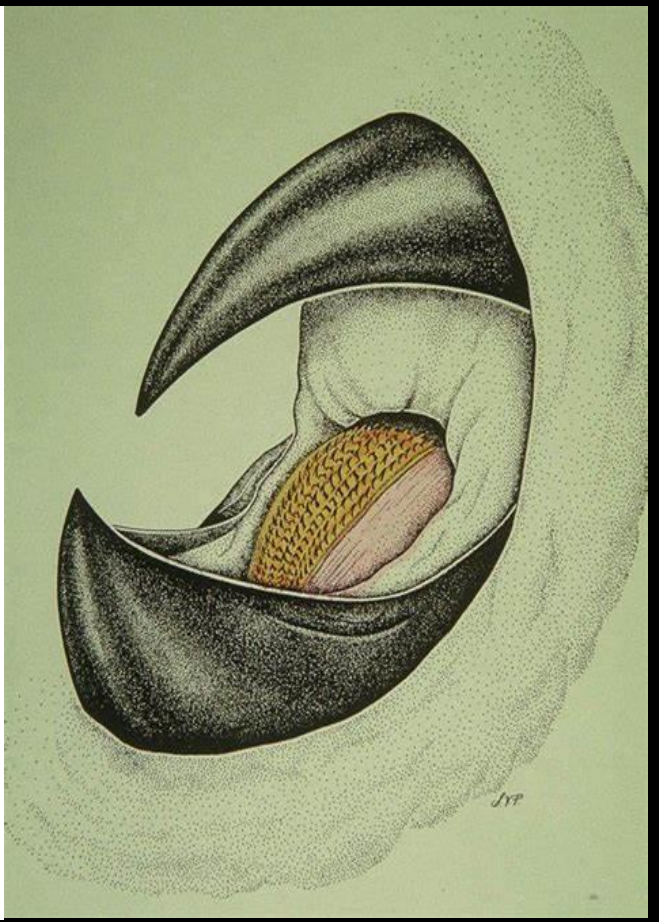
OCTOPUS ANATOMY

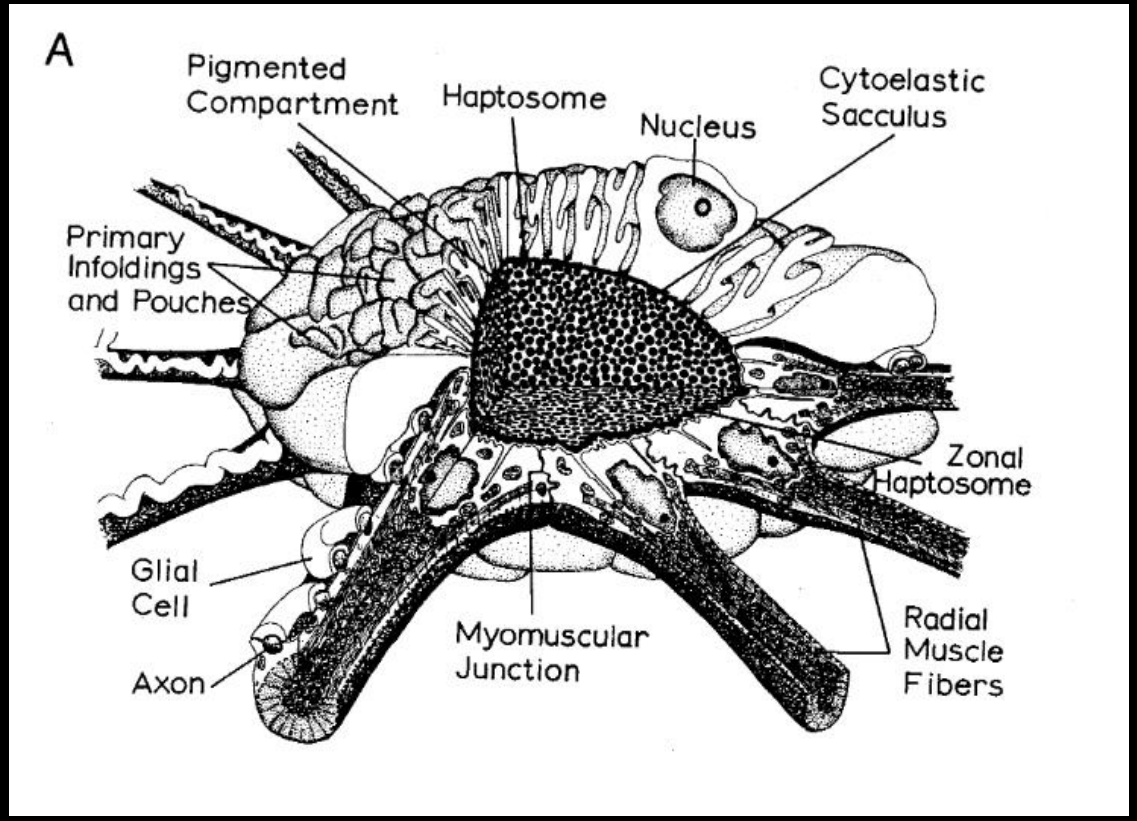
- 9 brains
- Olfactory suction cups
- Radula
- 3 hearts
- Chromatophores
- Hemocyanin





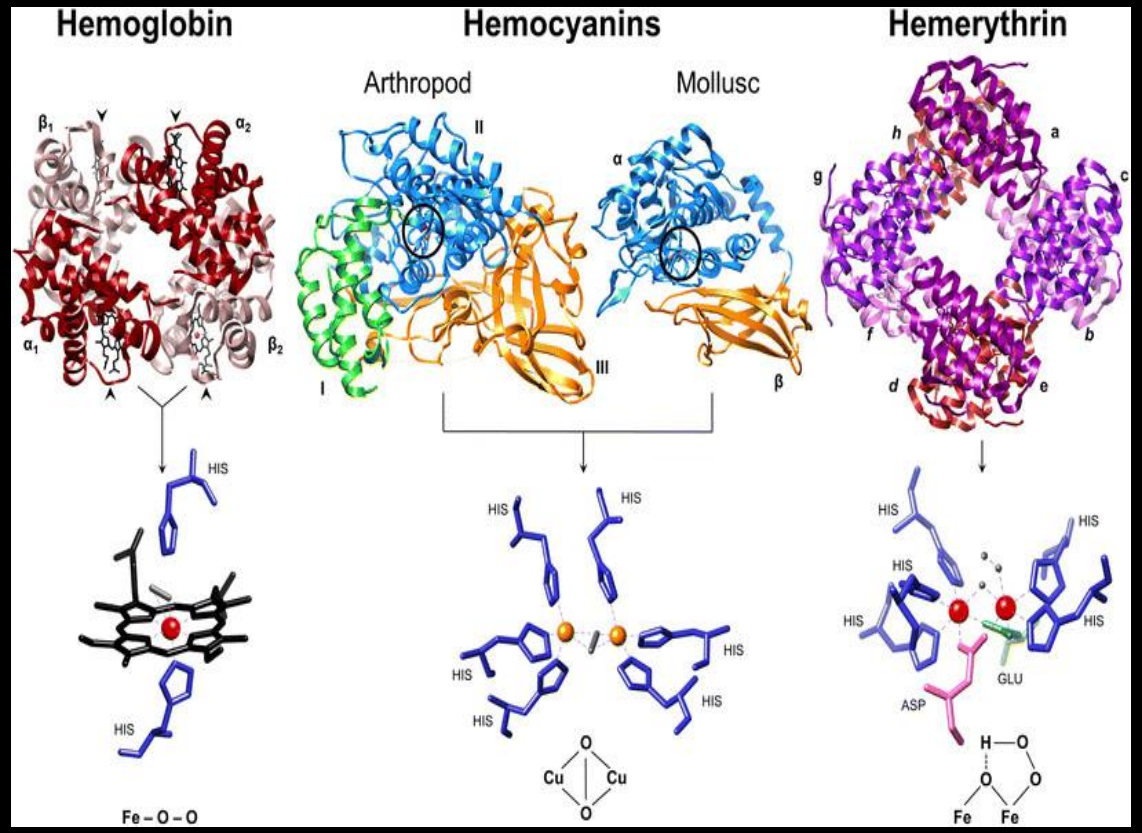
CHROMATOPHORES

- 1970
- Neuromuscular ligand
- Pigment
- Depolarization
- Diverse
- Varying pigments
- Cluster-Density differs



HEMOCYANIN

- Copper
- Orbital
- Dipole
- Direct oxygen bonding
- Optimized oxygen bonding at low temperature



TENTACLES

- 4 different types of sensors
- Type 3 photosensitive
- GTK ligands
- Chemo-Tactile learning
- Longitudinal and transverse muscles
- Regenerative

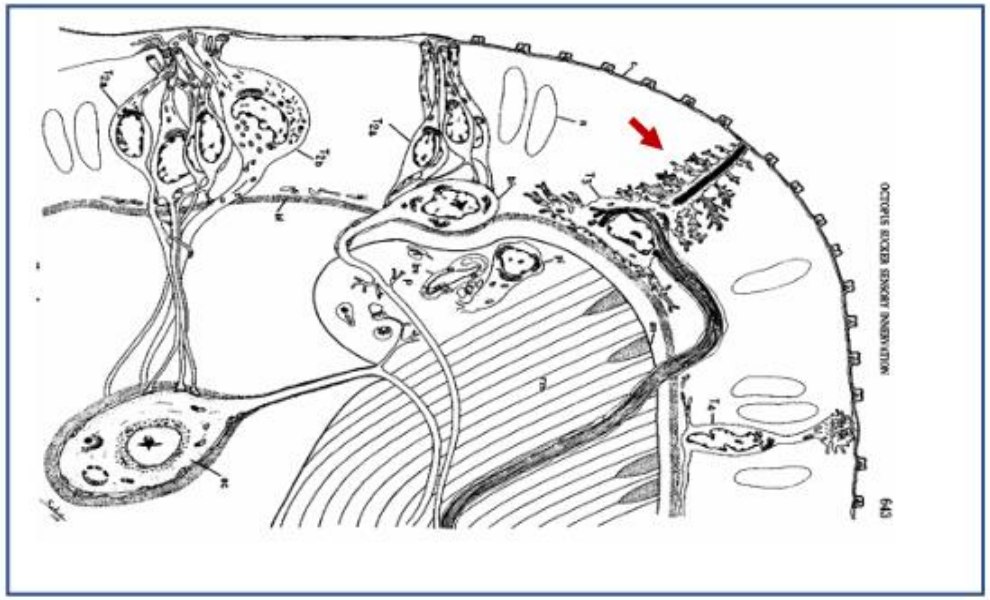
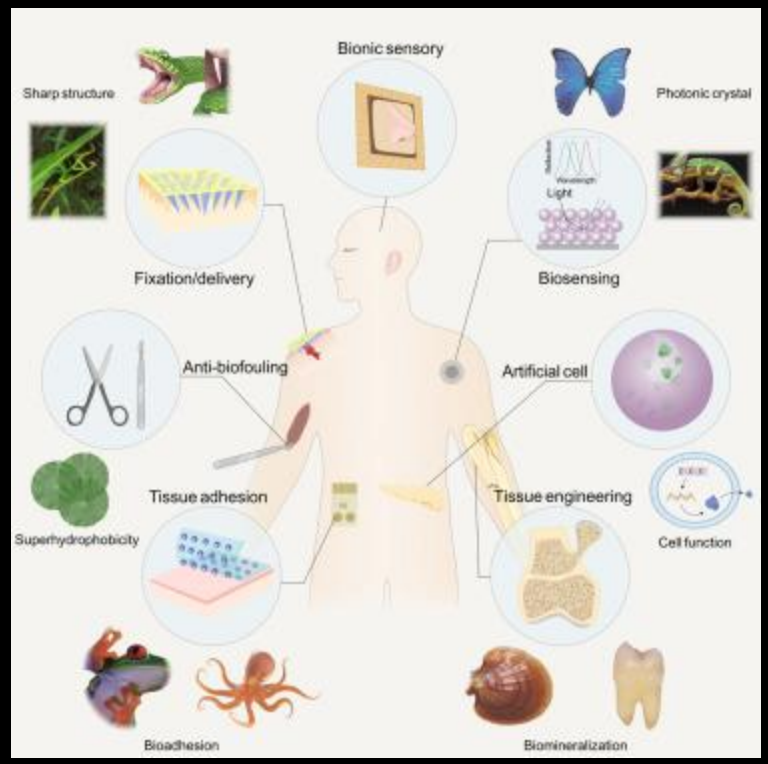


Figure.7. Summary of the four specialized sensory receptor cell types (T2a, T2b, T3 and T4) found in the epithelium rime of the sucker has been investigated by Graziadei and Gagne,1976. The cell type with which we are concerned here is cell Type 3, which occurs in the epithelium over the infundibular muscle (indicated by arrow).

WHAT CONVERGENT EVOLUTIONARY FEATURES DO OCTOPUSES SHARE WITH WHAT OTHER ANIMALS?

OCTOPUSES IN BIOMEDICAL SCIENCE

- 6th century BCE Alcmaeon of Croton
- Robotics
- Neuroscience (functional-structural)
- Regenerative medicine
- Interest increasing



ROBOTICS

- Immunological
- Mechanical
- Biomechanical
- Hydrostatic skeleton reaching movement
- Nervous system control

Every muscle in the model exerts the following force

$$f(t) = A\left\{a(t)F_a\left[\frac{l(t)}{l_0^m}\right]F_v\left(\frac{v}{v_{max}}\right) + F_p\left[\frac{l(t)}{l_0^m}\right]\right\} \qquad (10)$$

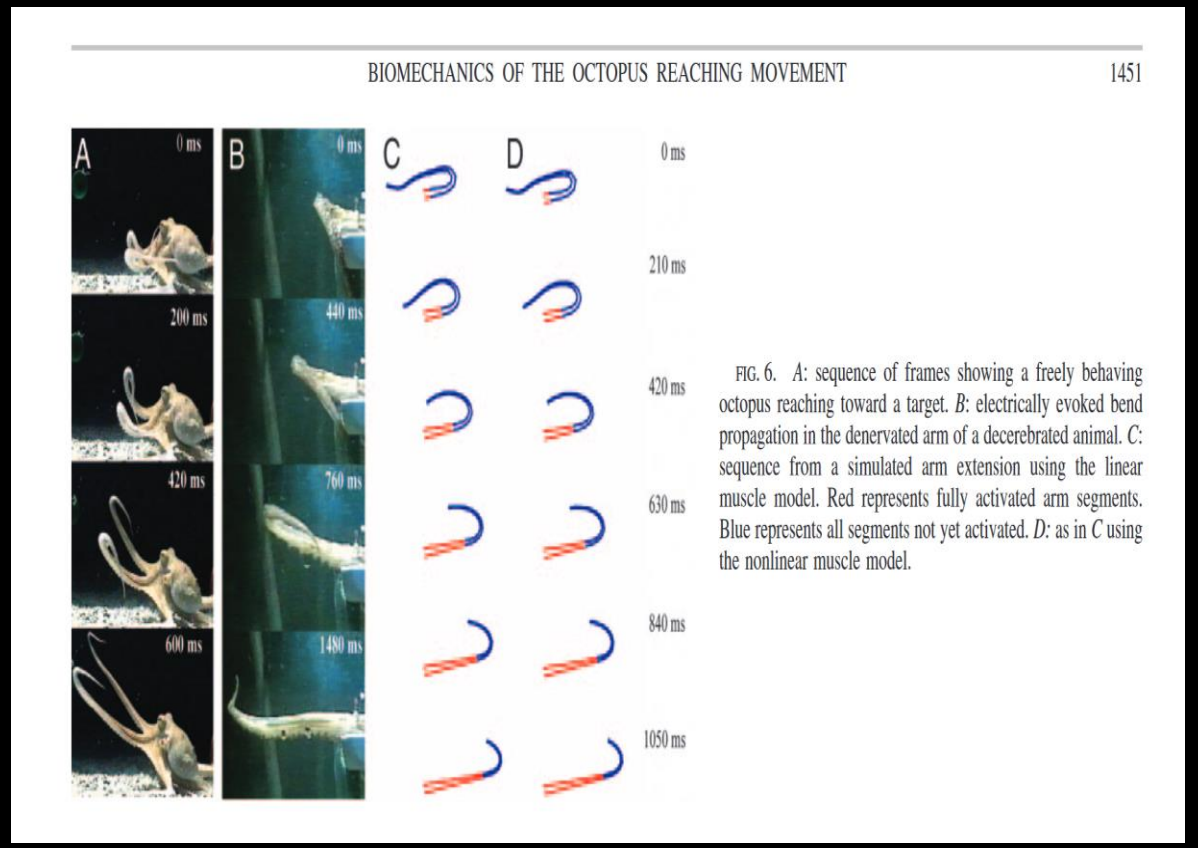
where A is the cross-sectional area of the muscle, $a \in [0, 1]$ is dimensionless activation function, $l(t)$ is muscle length, and l_0^m is the specific length of the muscle at which active muscle force achieves its peak value (terminology after Zajac 1989). The active stress F_a equals the normalized active force (Fig. A) multiplied by the maximum stress. The dimensionless

$$A^{longitudinal} = \frac{1}{2} w_r d = \frac{1}{2} w_r^2$$

$$A^{transverse} = l_r d,$$

where w_r and l_r are the relaxed lengths[6] of the transverse and longitudinal segmental muscles, respectively; and d is the depth of the segment, which equals w_r at the initial relaxed shape of the arm. The factor of ½ in $A^{longitudinal}$ is ascribed to the fact that there are a total of $2n$ longitudinal muscles in the model for n segments (and only $n + 1 \cong n$ transverse muscles in the model).

The activation dependency on time is expressed by $a(t)$ and described below. Note that we assume a linear scaling of the force with the activation parameter. This is an approximation



BIOINSPIRED LOCOMOTION AND GRASPING IN WATER: THE SOFT EIGHT-ARM OCTOPUS ROBOT

- Electrolycra
- 8 servo's
- Visual control, central control and peripheral control
- 260 cm × 170 cm × 20 cm fresh water
- Object 1: rectangular cross-section wooden bar, 25 × 30 mm, 75 g weight. – Object 2: round polymeric cylinder, 25 mm outer diameter, 58 g weight. – Object 3: round polymeric cylinder tube, 60 mm outer diameter, 250 g weight. –Object 4: round aluminium tube, outer diameter 25 mm, 478 g weight.

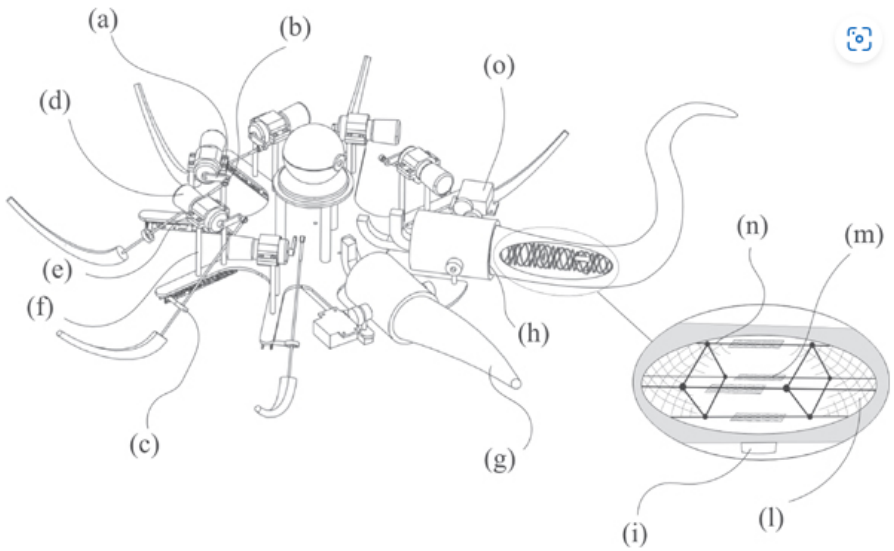


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Figure 3. The locomotion components of the OCTOPUS: crank (a), spherical joint (b), spherical bearing (c), motor (d), scaffold (e) and pillars (f); and the manipulation components: insulating skin (g), cable servo-motor (h), contact sensors (i), braided sheath (l), stretch sensors (m), SMA springs (n), base controlling servo-motor (o).

OCTOPUS RESULTS

- Not omni-directional
- Independent of terrain
- One of first soft robotics with push and manipulation
- Slightly slower than real octopuses
- Mimics hydrostatic movement

Table 4. Errors on the estimation of angles for pose reconstruction.

Virtual segment number	Angle error mean (deg)	Angle error max (deg)	Angle error min (deg)
1	5.67	14	2
2	7.44	24	1
3	6.11	14	0
4	5.78	27	1
5	6.67	29	0

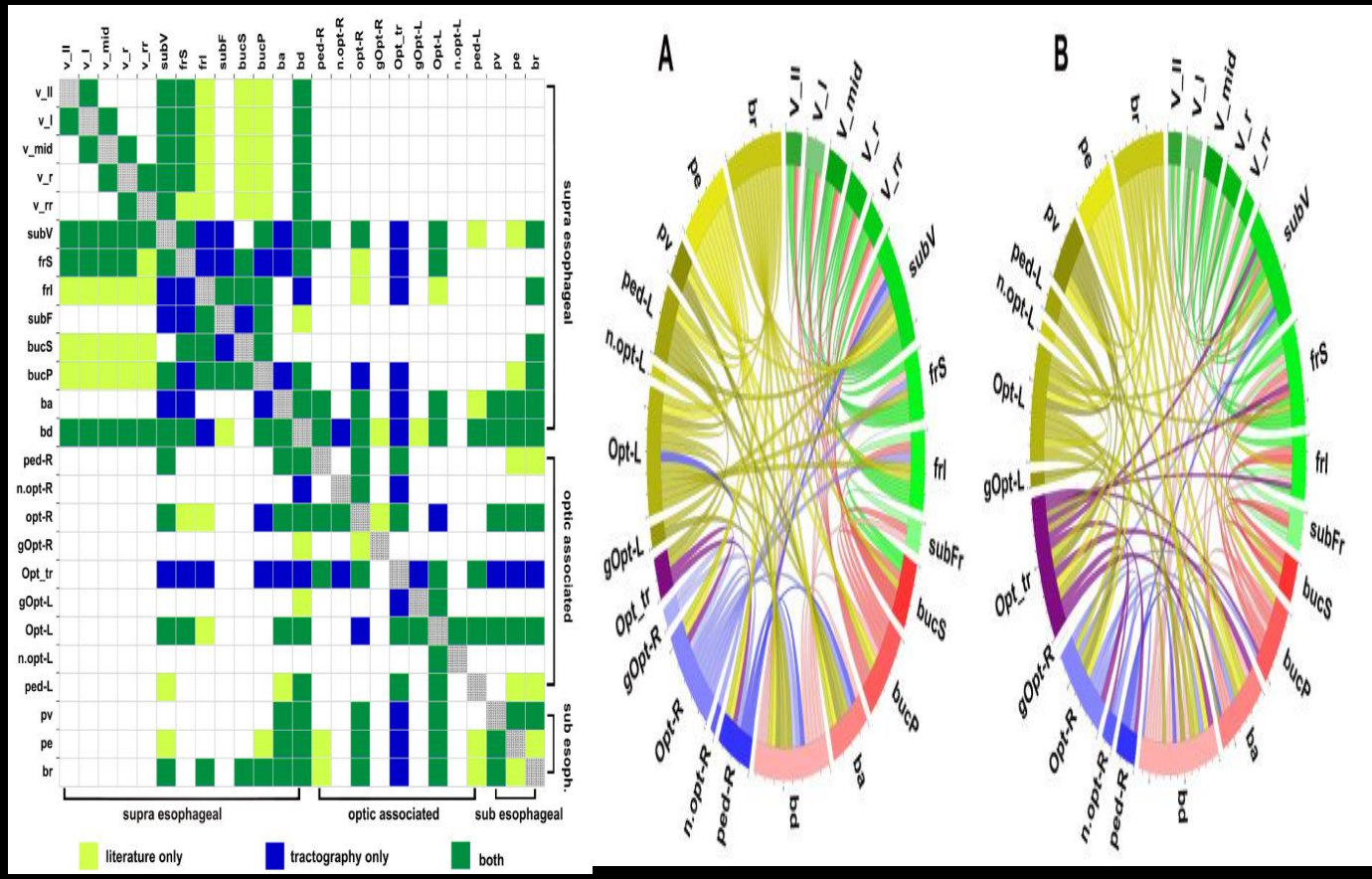
Table 3. Sensors activation (hit ratio) while grasping different objects.

Sensor no.	Object 1	Object 2	Object 3	Object 4
1	13/20	17/20	18/20	17/20
2	17/20	18/20	19/20	20/20
3	18/20	18/20	20/20	20/20
4	17/20	20/20	20/20	20/20
5	13/20	17/20	17/20	18/20

WHAT BIOMEDICAL DEVICES HAVE BEEN CONSTRUCTED AFTER ANIMAL MODELING?

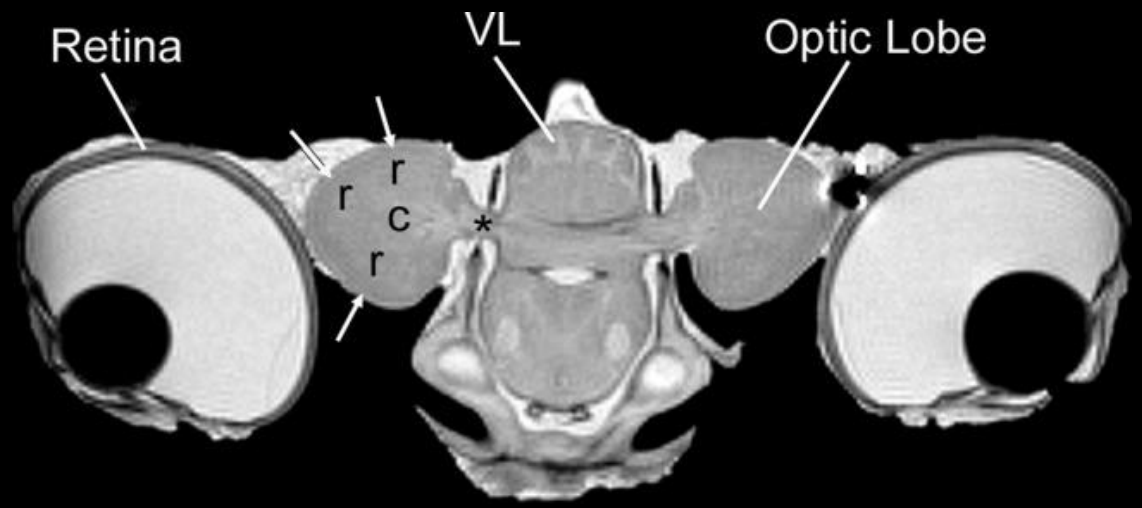
NEUROSCIENCE

- Imaging
- Functional/structural
- Non-Myelinated
- Genomics
- Octopuses = Monkey rights



OCTOPUS VISUAL SYSTEM: A FUNCTIONAL MRI MODEL FOR DETECTING NEURONAL ELECTRIC CURRENTS WITHOUT A BLOOD-OXYGEN-LEVEL-DEPENDENT CONFOUND

- 50 g and 110 g female
- White LED pulses
- Optic nerve and OL removed
- Single shot GE and EPI
- FOV = 2 x 2cm2, matrix size = 64 x 64 (in-plane resolution = 0.31 x 0.31 mm2), slice thickness = 1 mm, TR = 1 s and flip angle = 70 degrees (Ernst angle)
- T-test with GLM



OCTOPUS MRI RESULTS

- Monte Carlo cluster sizes
- findings (10,11,13,17), hemodynamic.
- RF coil few cm
- Dipole voltage gated ions
- "More sensitive superconducting quantum interference devices"

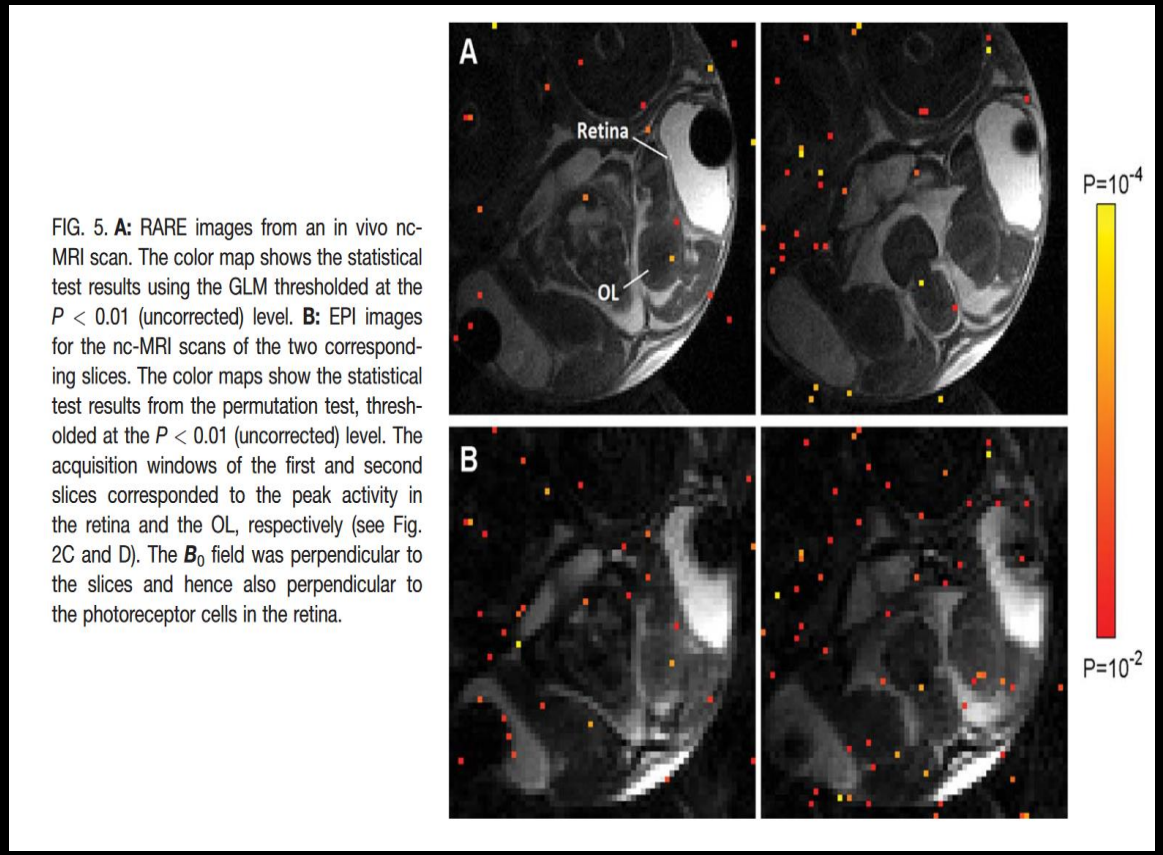
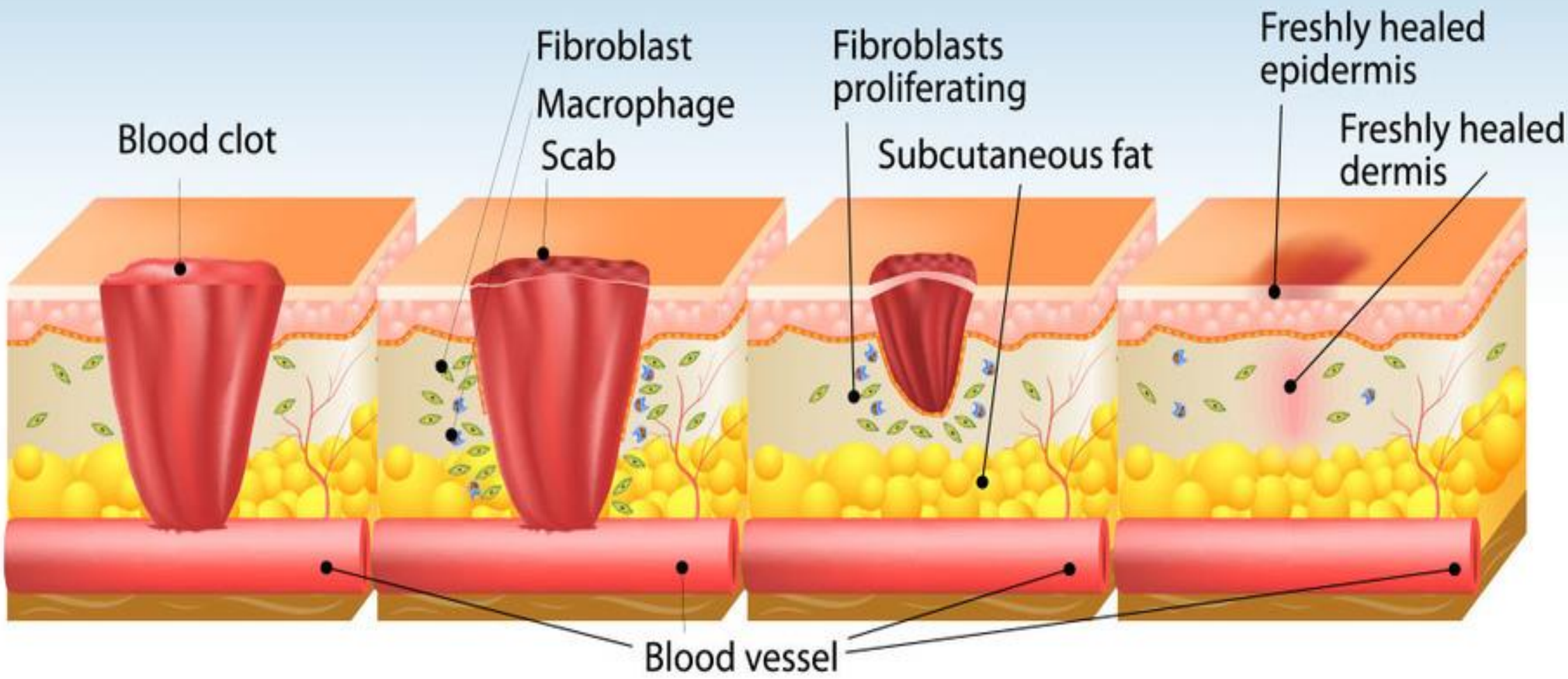


FIG. 5. **A:** RARE images from an in vivo nc-MRI scan. The color map shows the statistical test results using the GLM thresholded at the $P < 0.01$ (uncorrected) level. **B:** EPI images for the nc-MRI scans of the two corresponding slices. The color maps show the statistical test results from the permutation test, thresholded at the $P < 0.01$ (uncorrected) level. The acquisition windows of the first and second slices corresponded to the peak activity in the retina and the OL, respectively (see Fig. 2C and D). The $\boldsymbol{B}_0$ field was perpendicular to the slices and hence also perpendicular to the photoreceptor cells in the retina.

HOW WOULD YOU INCORPORATE OCTOPUSES INTO YOUR RESEARCH? WOULD IT PROVIDE INTERESTING RESULTS?

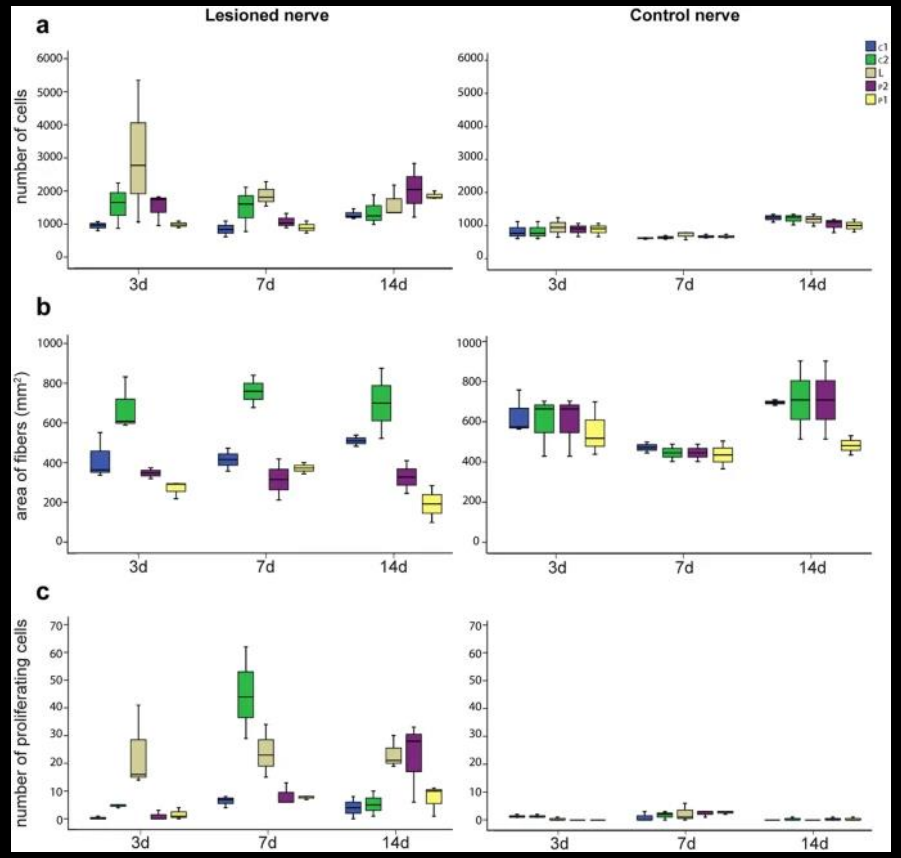
Stages of Wound Healing



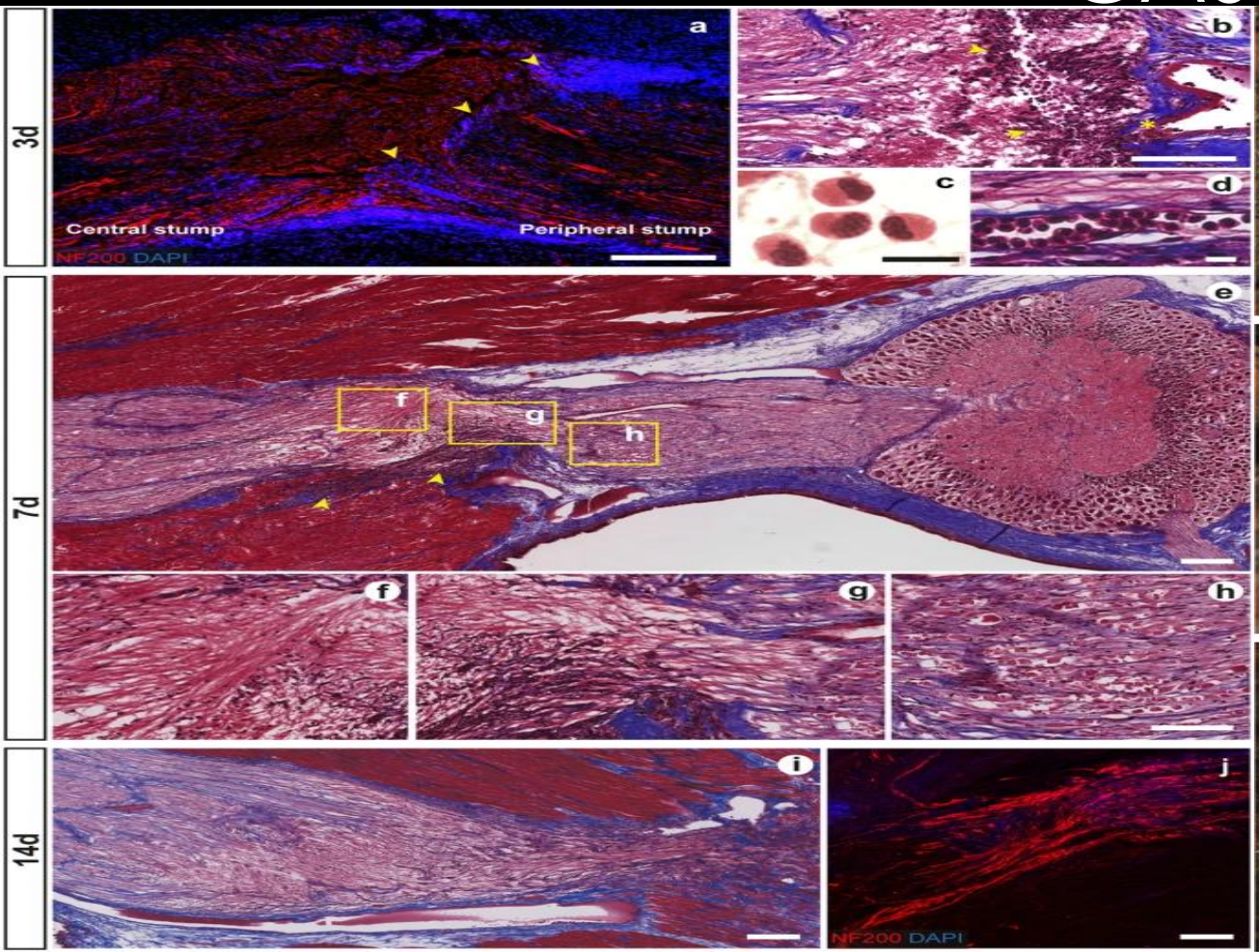
Bleeding **Inflammatory** **Proliferative** **Remodeling**

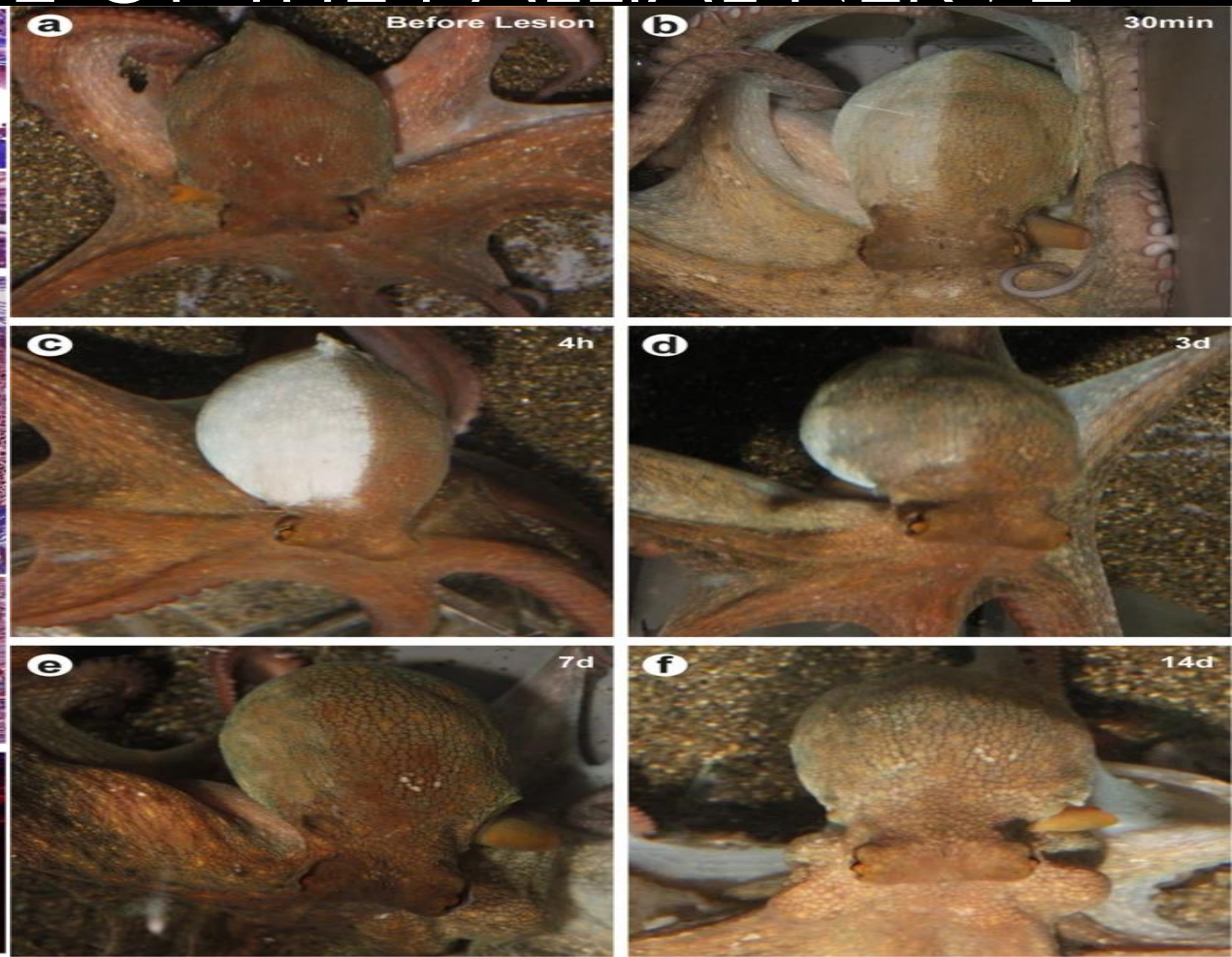
REGENERATIVE MEDICINE

- Regenerates “cornea, peripheral nerves and neural pathways within the central nervous system”
- Lesions in octopuses (12 male, 5 female), 1800 cells per stack
- 60 seconds predatory behavior
- 1-2 days later brown pattern
- 3-5 days later full recovery



NERVE DEGENERATION AND REGENERATION IN THE CEPHALOPOD MOLLUSK OCTOPUS VULGARIS: THE CASE OF THE PALLIAL NERVE





WHEN WERE OCTOPUSES GRANTED THE SAME RIGHTS AS PRIMATES?