

Design Issues - Sensing

nerve endings

Meissner corpuscles

Merkel discs

Ruffini corpuscles

Pacinian corpuscles

Golgi tendon organs

Proprioceptors

temperature, pain

velocity, light touch

pressure, low freq

pressure, skin stretch

acceleration, high freq

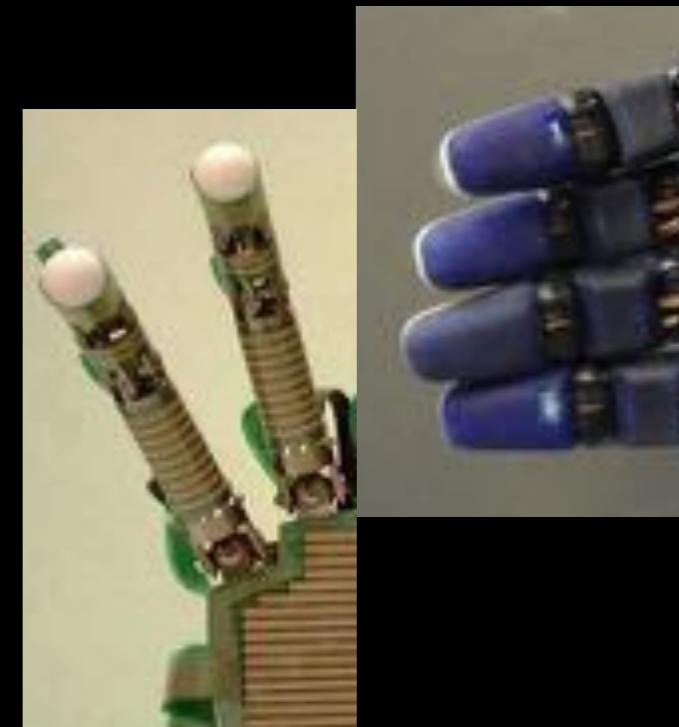
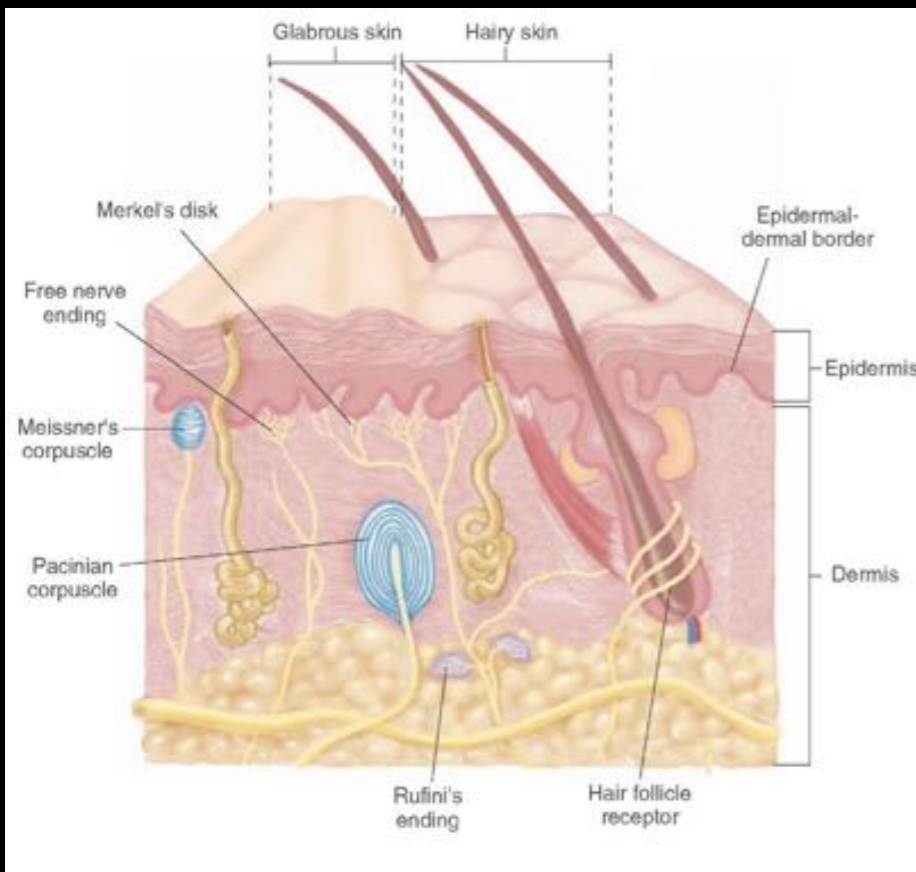
tendon stretch

position

FSR, QTC, etc.

strain gauges

hall effect, optical...



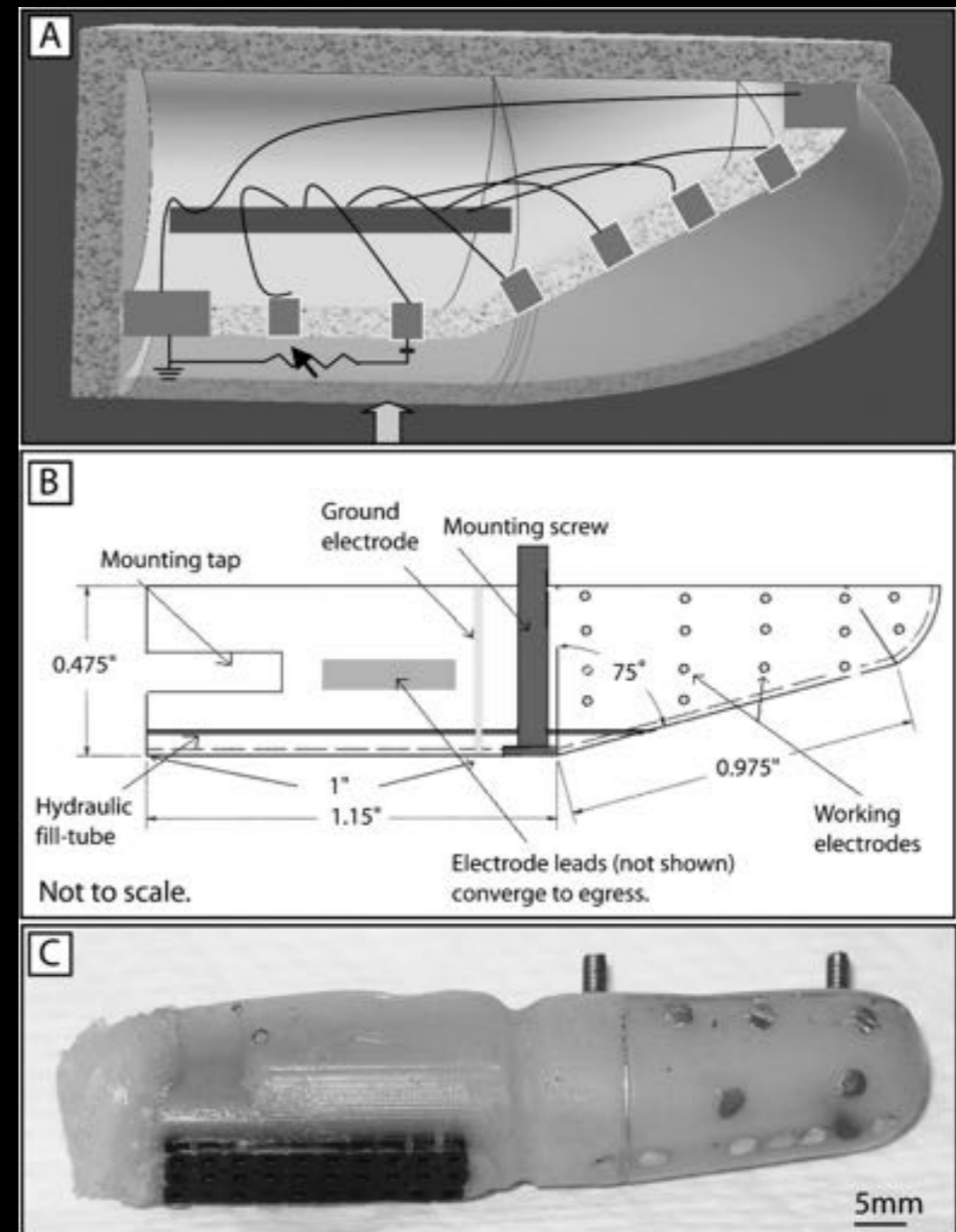
Design Issues - Sensing

Compensating with position sensors?

Electric field based tactile sensor
(Gerald Loeb, USC)



Electric field imaging (Josh Smith, Intel)



Design Issues – Control

It has been observed that muscle coordination patterns switch from position control to isometric force control ~65 ms before contact

For humans, forces modulated by sensor feedback w/in 70ms

Typists may have 100-200ms interval between keystrokes

Pianists may have 80-100ms interval between notes

Typical latencies in a robotic hand/arm system may be 40ms

A hand moving at a typical reaching speed of 1m/s will move 4cm in 40ms