Integration of sensory and motor devices with the human body: <u>the neuroprosthesis</u>

Dr. Jeno Pali, Ph.D.

Biocybernetics Ltd.

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For a long time people have been concerned about the question whether it is possible – and if it is then how it is possible – to create a bidirectional connection between the nervous system and prostheses, e.g. artificial limbs…..

Our present project is to develop the elements of a **neuroprosthesis** which will help those people who have lost their extremities or suffered spinal cord injury. The project is based on the European patent **EP1360642** of **dr. Jeno Pali** and supported by the European Union. We have just completed a **prototype** of a **neuromorph artificial touch sensing device** and a **three-finger robot hand** with human-like fine motor control.

We are developing an **artificial synapse** comprising electric devices and stem cell technology now so that e.g. an artificial limb can be connected to the nervous system and thus both the human sensory and motor functions can be restored entirely.

A **neuroprosthesis** must involve both the human sensory and motor functions at the same time, creating a new, **artificial sensory-motor integration level** for the human body and for the human motor control system.

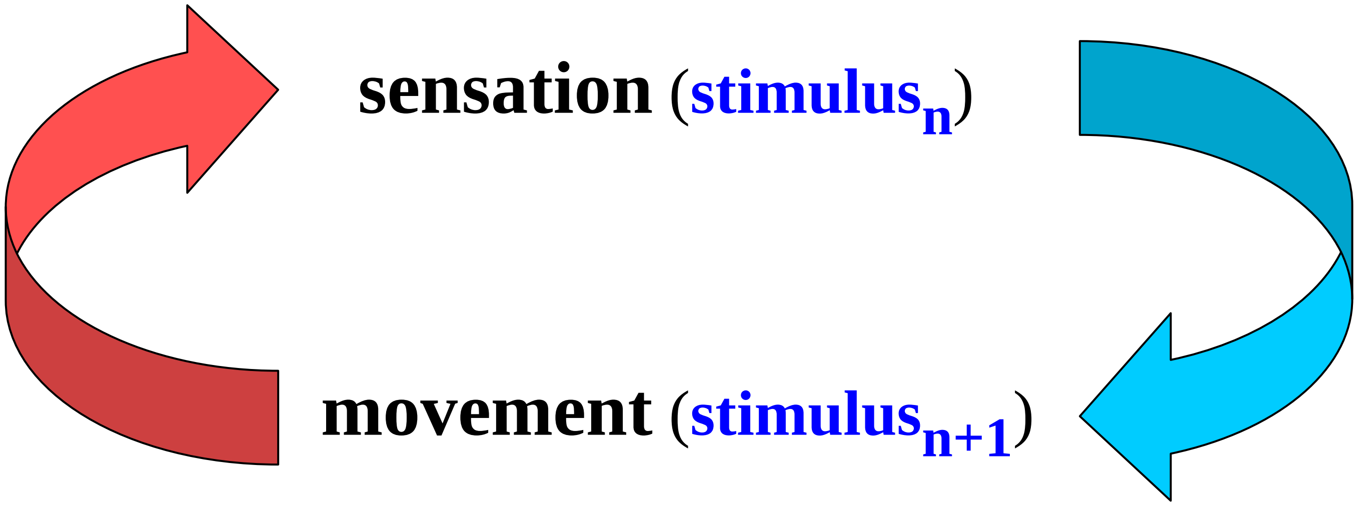
Levels of natural sensory-motor integration in the human:

Cerebellum

	Cerebellum	
Cerebral cortex (vision, hearing, somatosensation) →	**corticocerebellum**	→ **Voluntary movements:** speech, mimic, tools, art
Colliculus superior (vision, hearing, somatosensation) →	**spinocerebellum**	→ **Involuntary movements** of the head and limbs
Inner ear (linear and rotational acceleration) →	**vestibulocerebellum**	→ **Eye-movements balance, posture**

primary sensory neuron → **Spinal cord** → **moto-neuron** →
- **myotatic reflex**
- **nociceptive reflex**
- **vegetative reflex**

Operation of the natural sensory-motor integration levels of the human:



Artificial sensory-motor organization:

Artificial touch sensing device

radio signal

Artificial synapse

stimulator

mediating biological structure

sensation

A

B

C

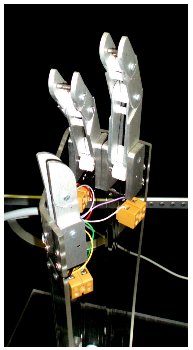
A’

B’

C’

motion

spinal cord (cerebellum)



prosthesis

2D and 3D movement modelling systems

radio signal

reader

mediating biological structure

Artificial synapse

Artificial sensory-motor organization consists of:

1., artificial touch sensing device (for neuromorph signal transduction)

2., artificial hand and musculature (the prosthesis itself)

3., artificial synapse (nerve regeneration techniques + electric devices + tissue manufacturing from stem cells)

4., 3-dimensional measuring, movement analyzing and modelling system

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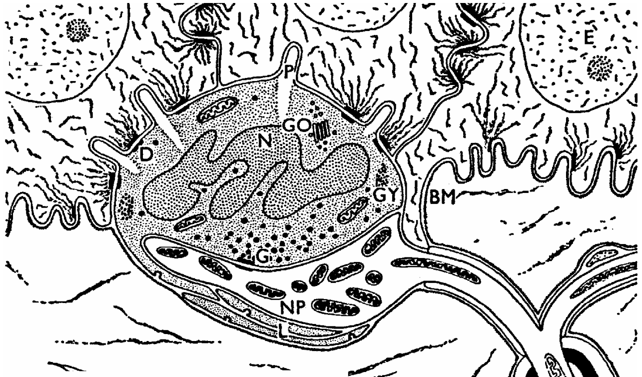
The human touch sensing organ is the fingertip:



MERKEL--receptor

/Iggo and Muir (1969)/

Analogous transducer:

– **amplitude**

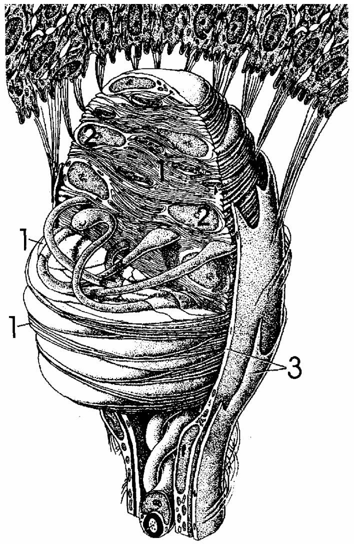
– **direction**

– **duration**

Adequate stimulus:

– **edge**

– **corner**



MEISSNER--receptor

/Krstic (1985)/

Digital transducer:

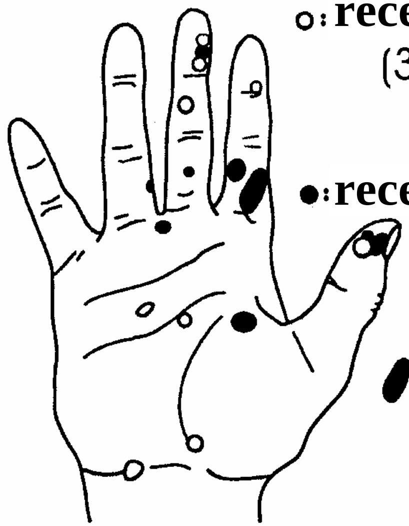
(yes / no)

– **changing of pressure**

Adequate stimulus: tap and flutter

(e.g. to read Braille)

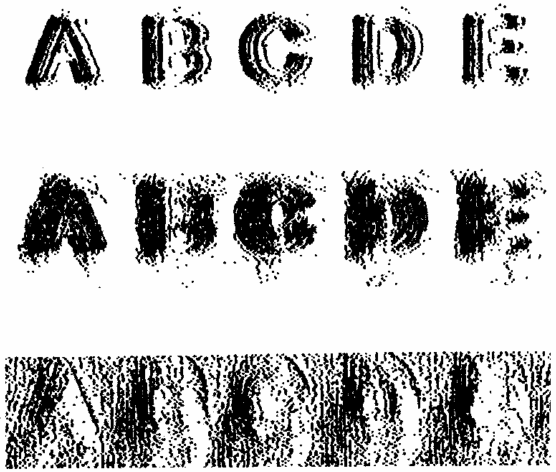
/Edin et al. (1995)/



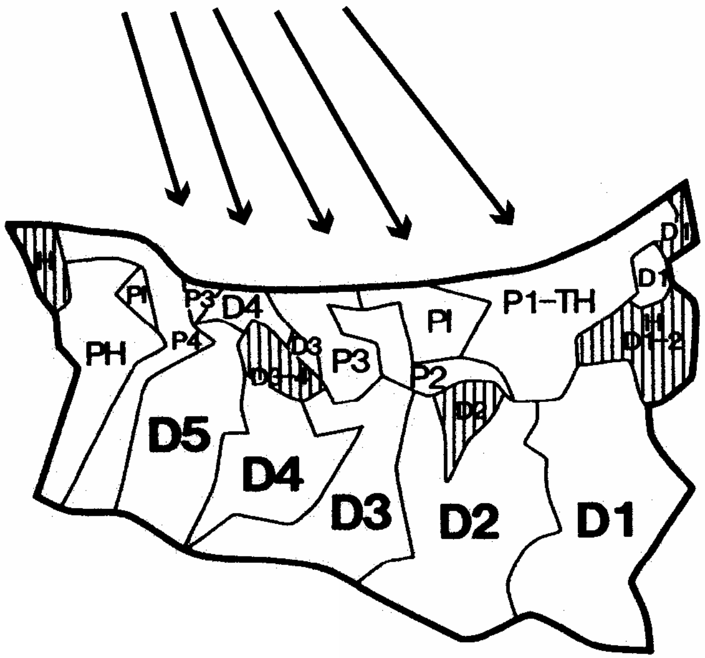
receptive field-- MERKEL receptor (3-4 mm)

receptive field-- MEISSNER receptor (3-4 mm)

receptive field-- PACINI receptor (10 mm)

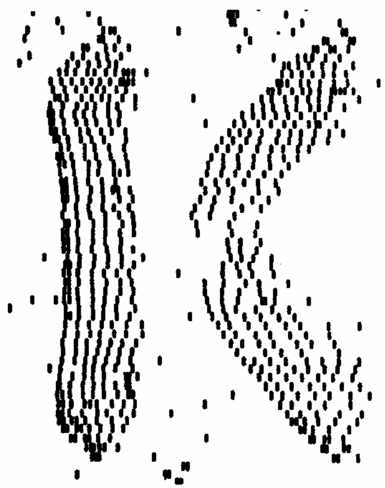


primary sensory neuron



primary somatosensory cortex

primary somatosensory cortex (3b)



/Phillips et al. (1988)/

Artificial touch sensing device:

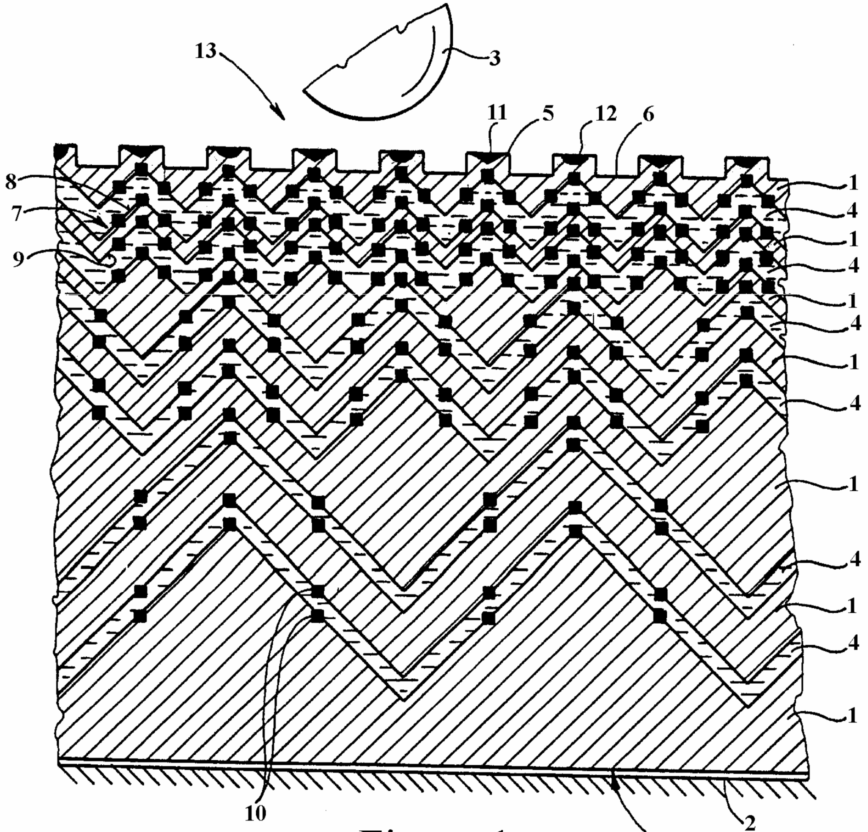


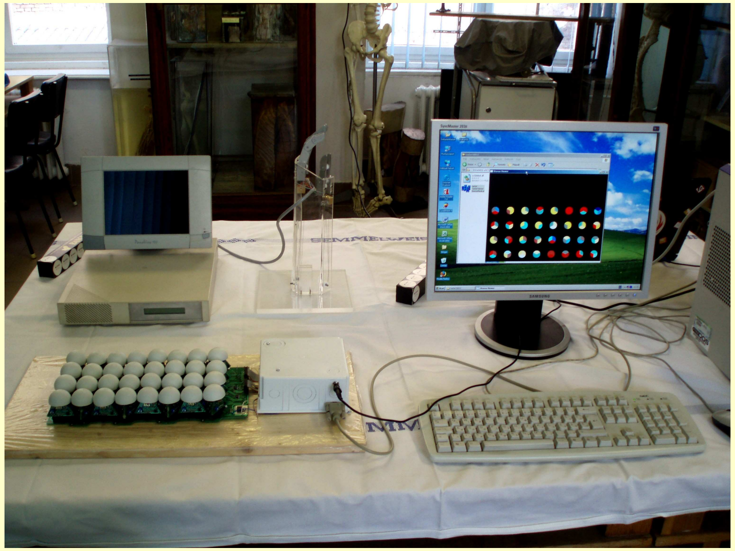
Figure 1

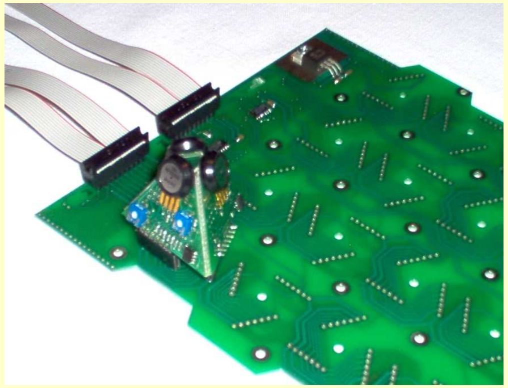
Dr. Jeno Pali, **EP 1360642** European patent

// http://v3.espacenet.com/textdoc?DB=EPODOC&IDX=WO02063549&F=0&QPN=WO02063549 //

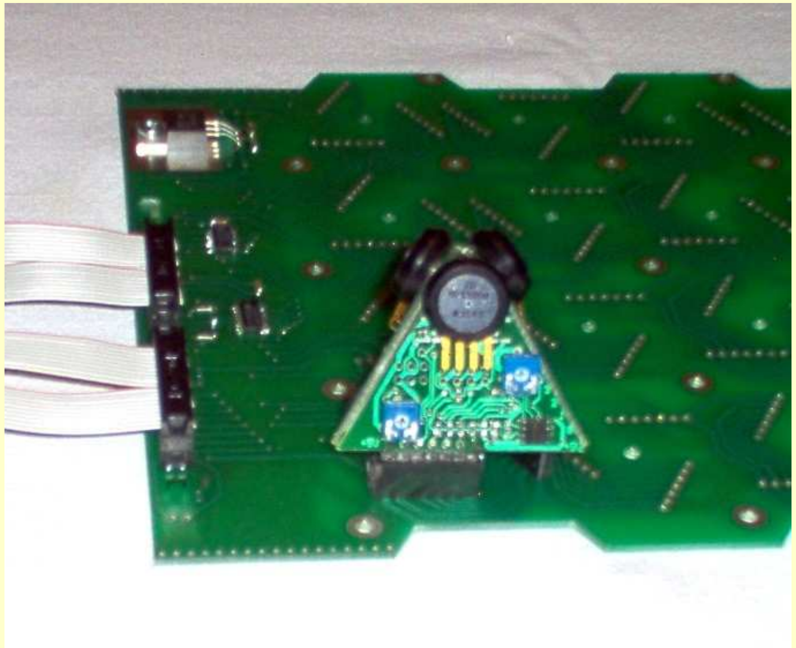
GVOP-3.3.1-05/12005-0011/3.0 financially supported EU-project

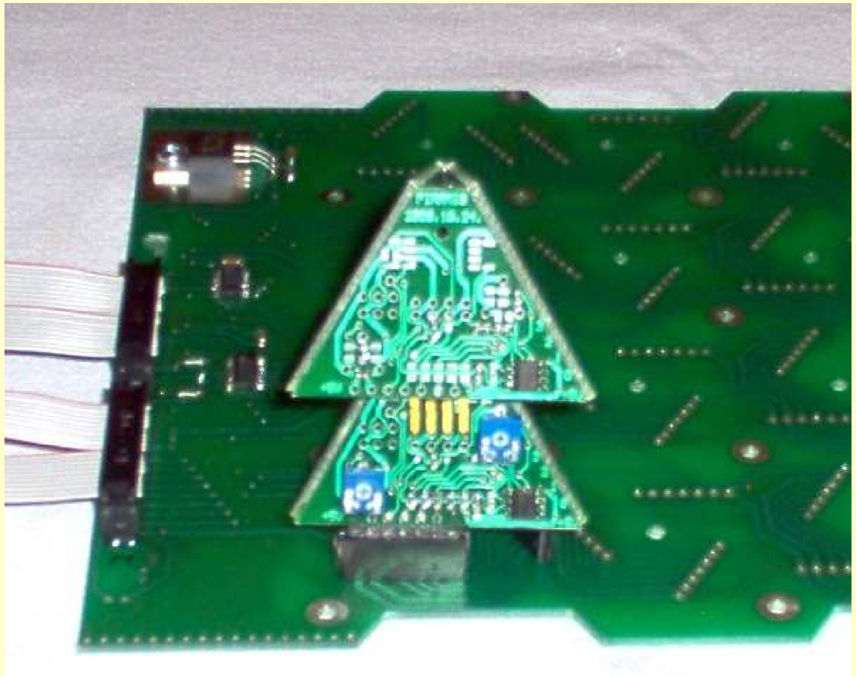
A prototype of the artificial touch sensing device:





A prototype of the artificial touch sensing device:





Artificial sensory-motor organization consists of:

1., artificial touch sensing device (for neuromorph signal transduction)

2., **artificial hand and musculature** (the prosthesis itself)

3., artificial synapse (nerve regeneration techniques + electric devices + tissue manufacturing from stem cells)

4., 3-dimensional measuring, movement analyzing and modelling system

The human hand performs the most sophisticated and complex movements:

Independently of the

- **shape**
- **size**
- **weight**
- **surface pattern,**

the human hand can handle, grip, lift and manipulate any object
with adequate compression force,
without any slippage or crunch.

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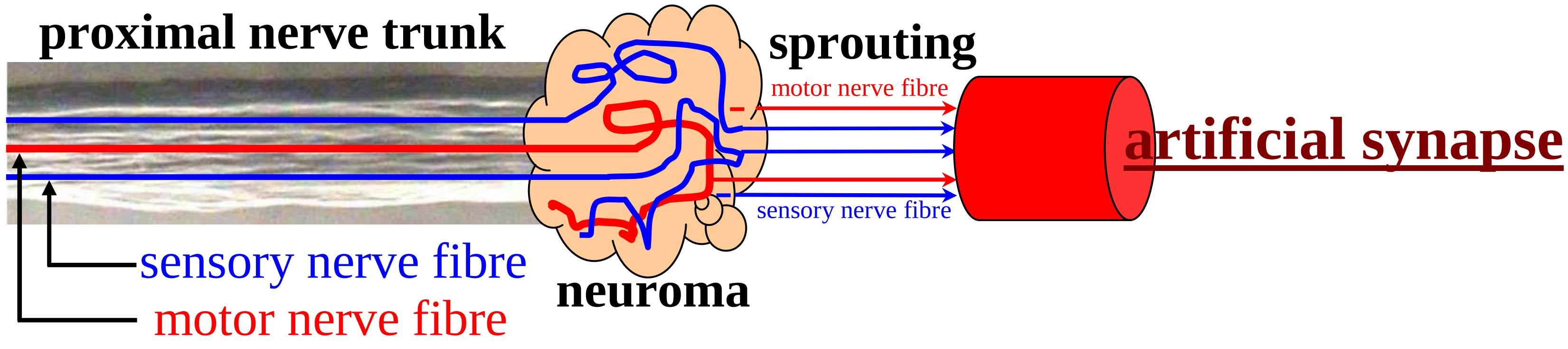
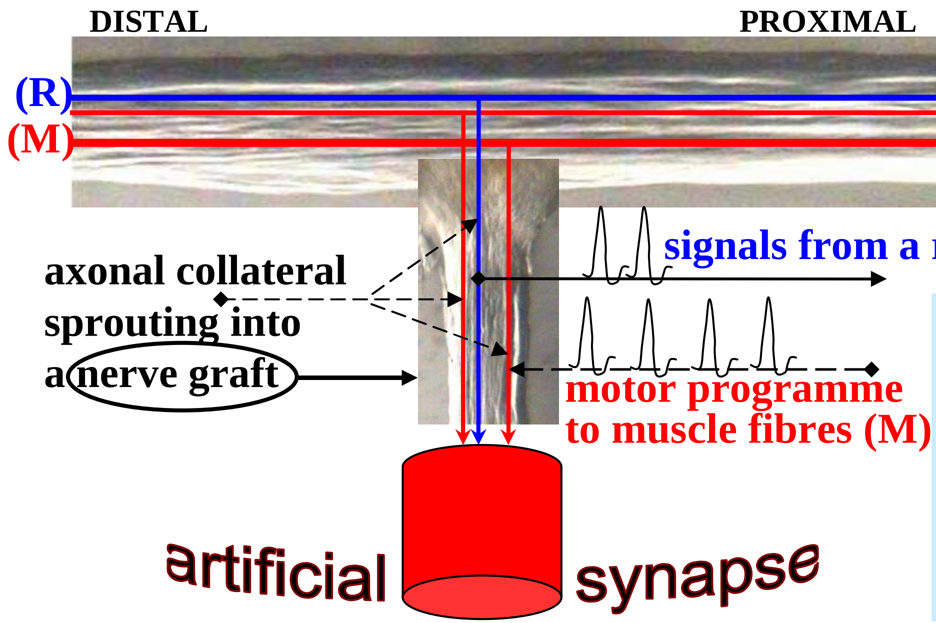
Which are the cases when we need an artificial synapse?

What kind of nerve regeneration techniques should be applied in these cases?

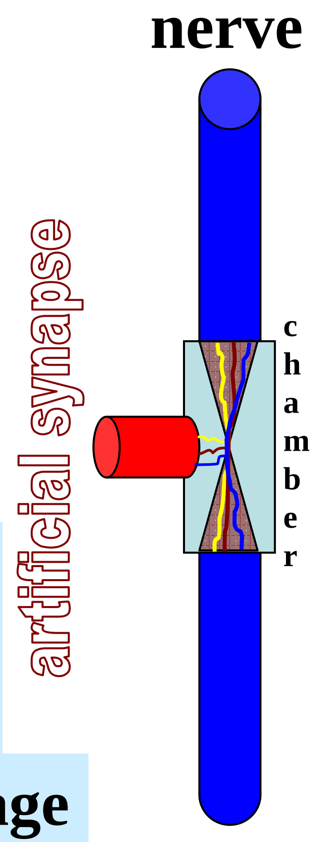
(A) Growing out nerve fibres from a proximal nerve trunk, in case of loss of extremities (e.g. amputation)



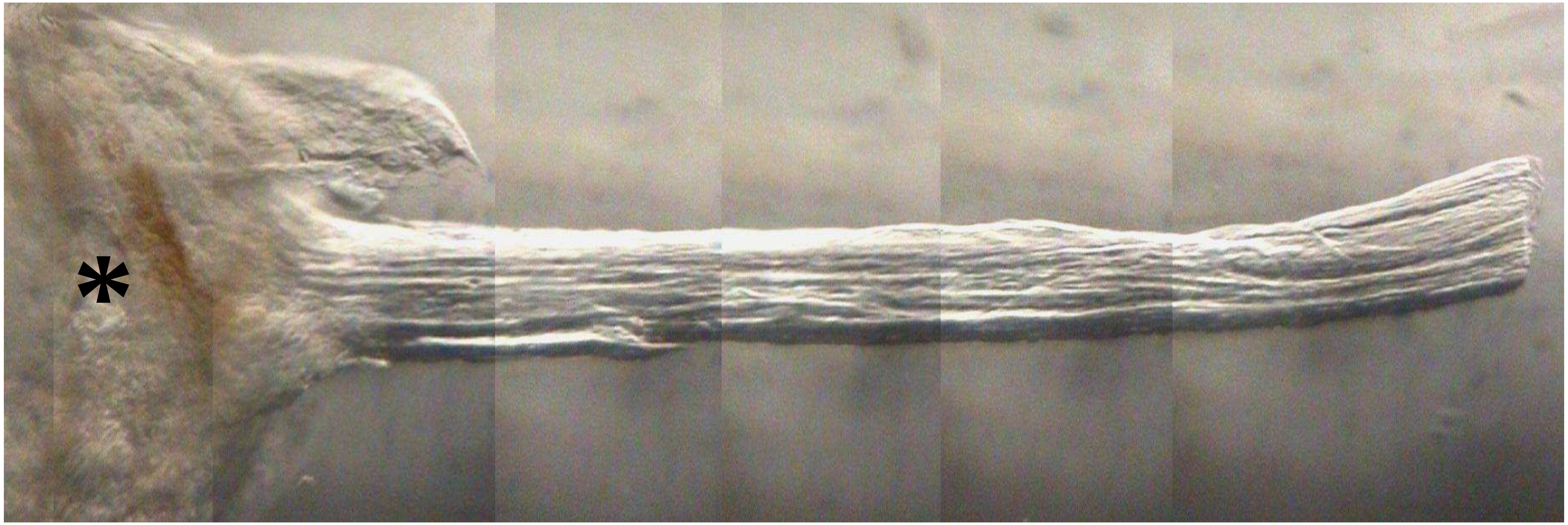
(B) End-to-side nerve coaptation, in case of paralized limbs after spinal cord injury

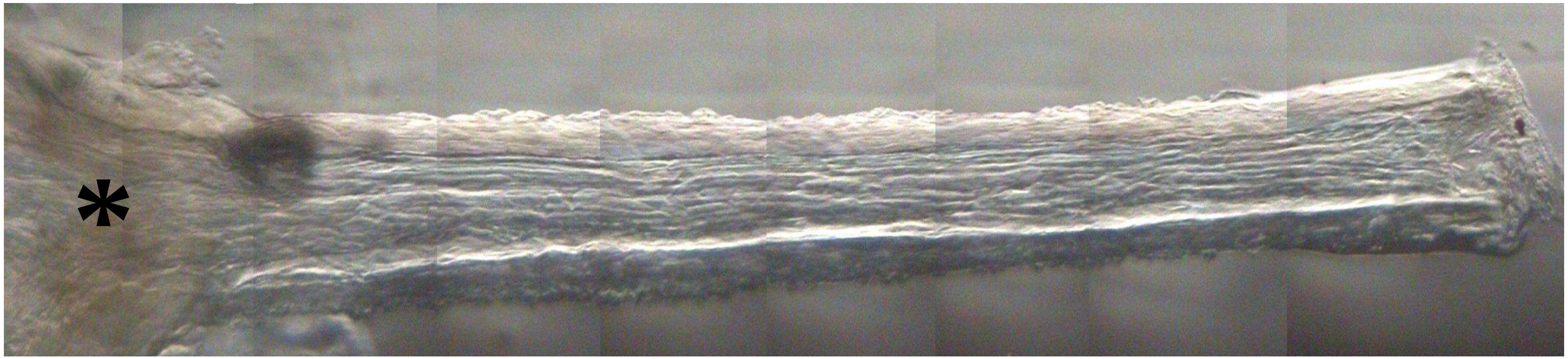


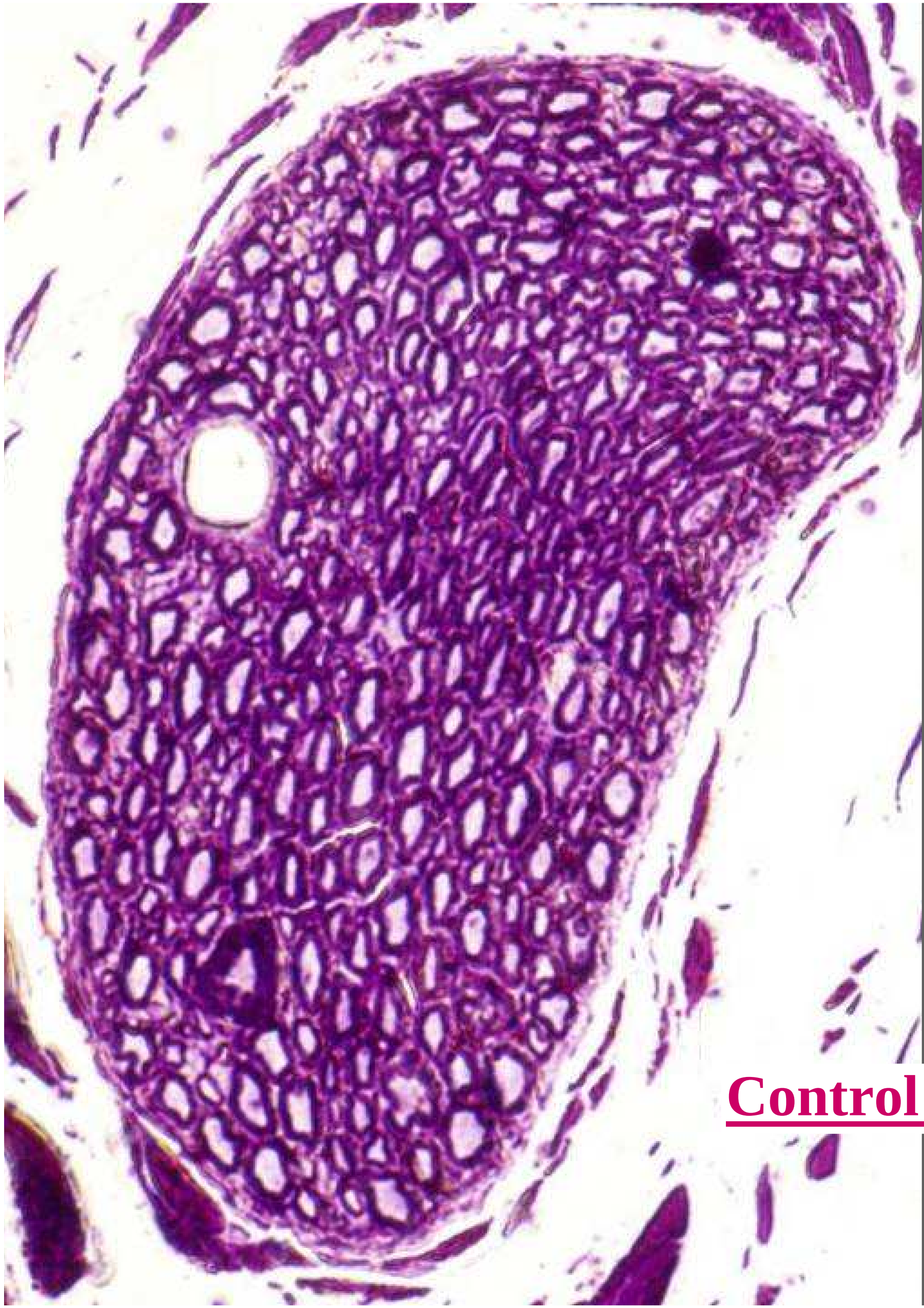
(C) Regeneration in a chamber following nerve excision, in case of extended nerve damage

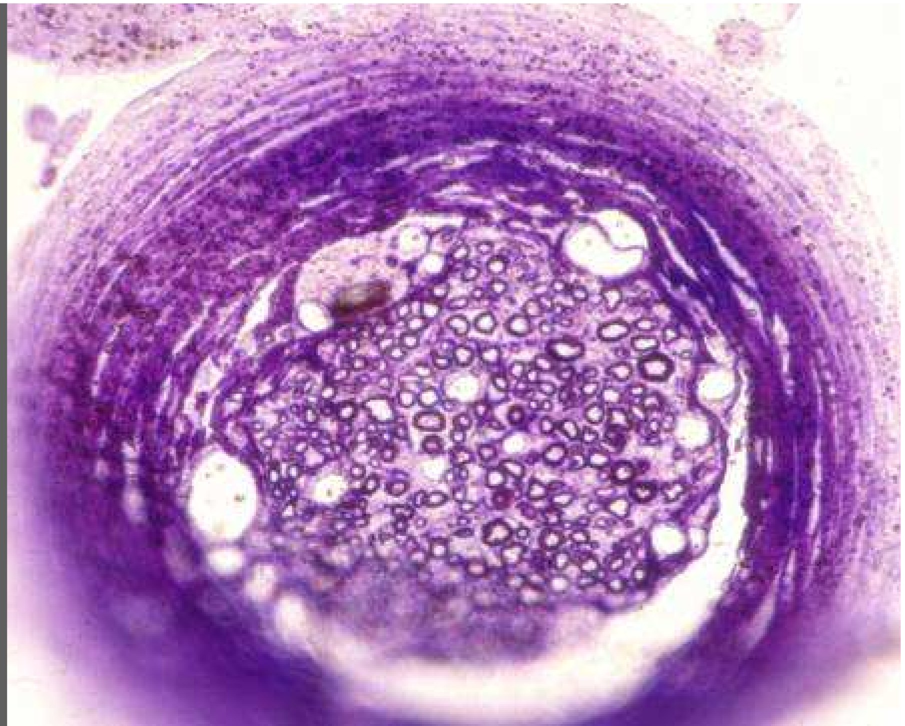


(A) Bundles of nerve fibres outgrown from nerve trunks*:









Outgrown regenerated nerve:

--278 nerve fibres

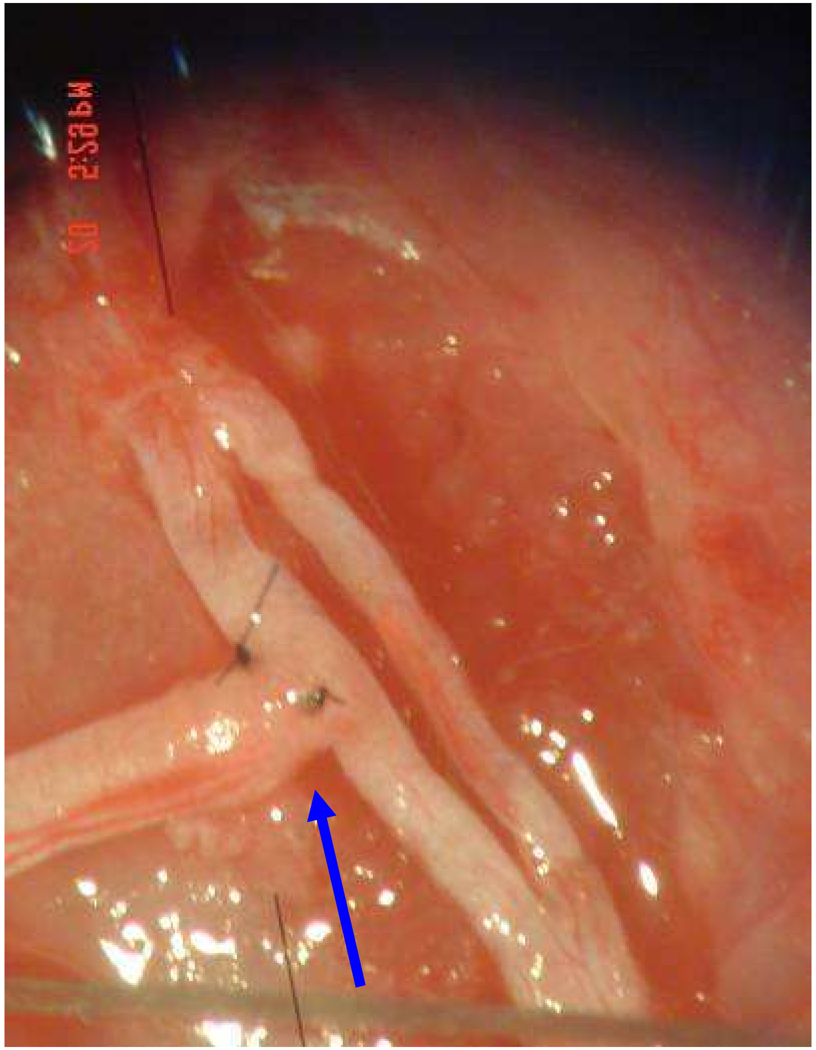
--17 blood vessels

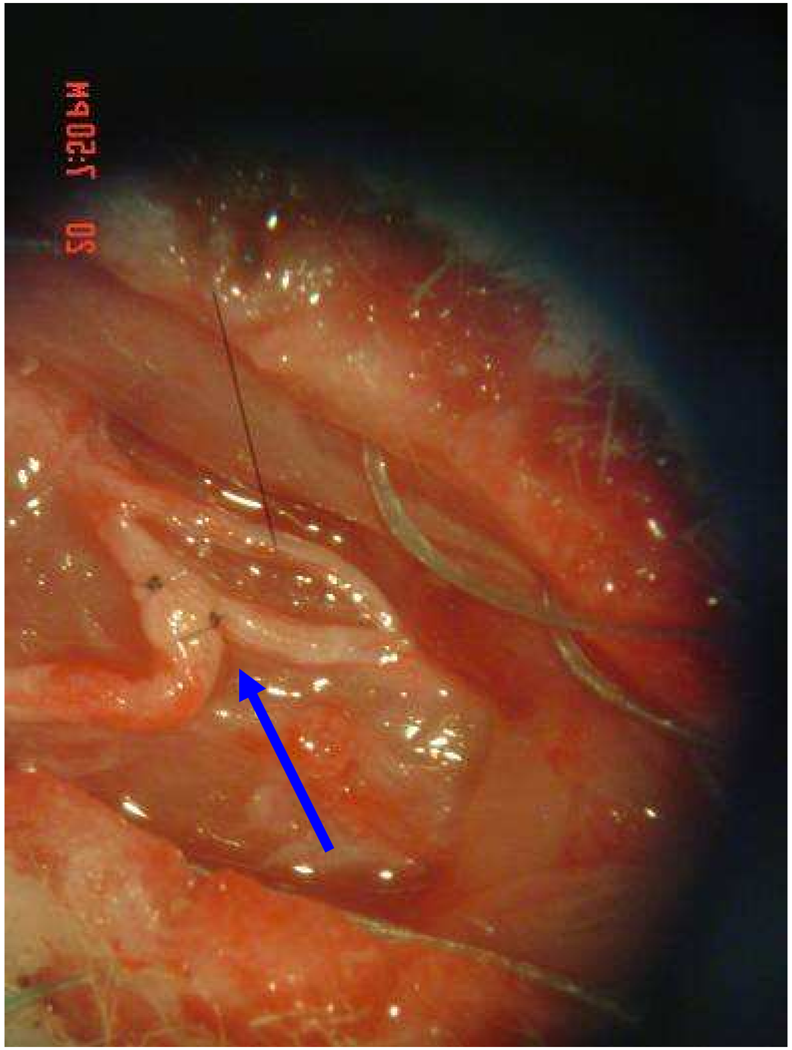
Control nerve:

--253 nerve fibres

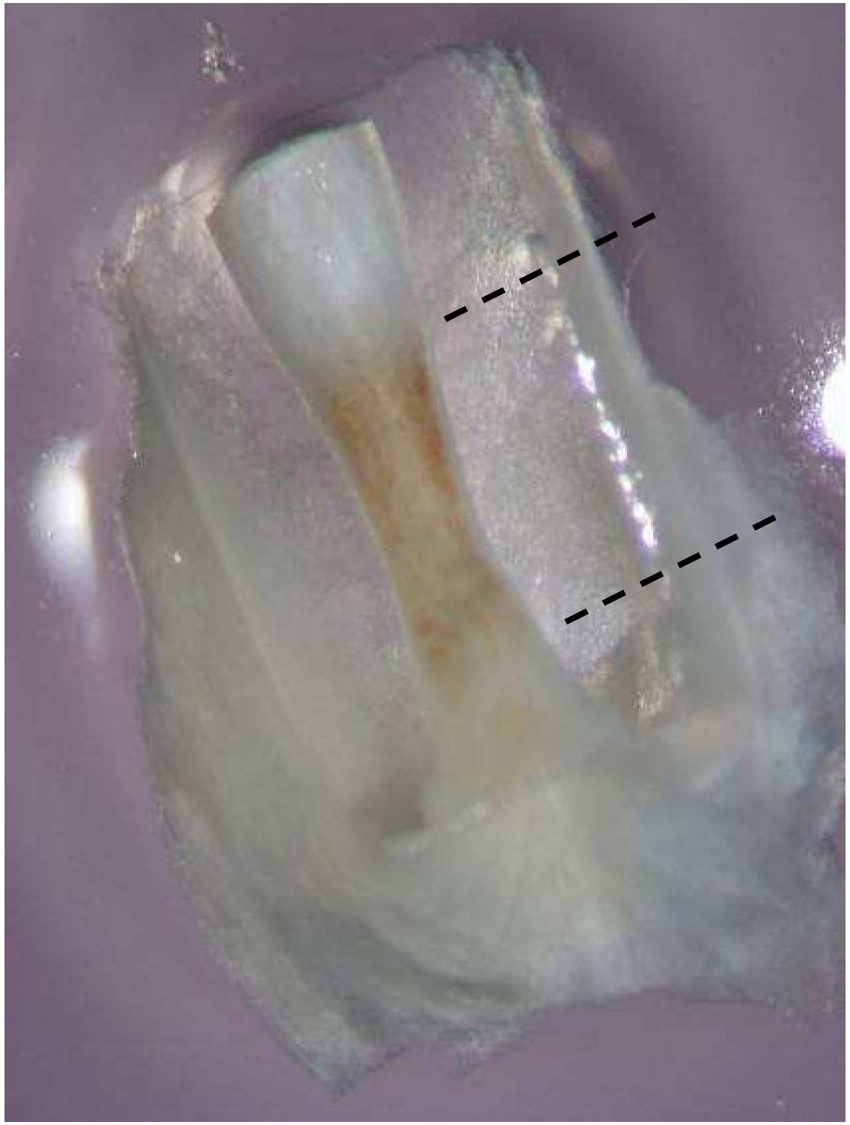
--1 blood vessel

(B) End-to-side nerve coaptation (arrow):

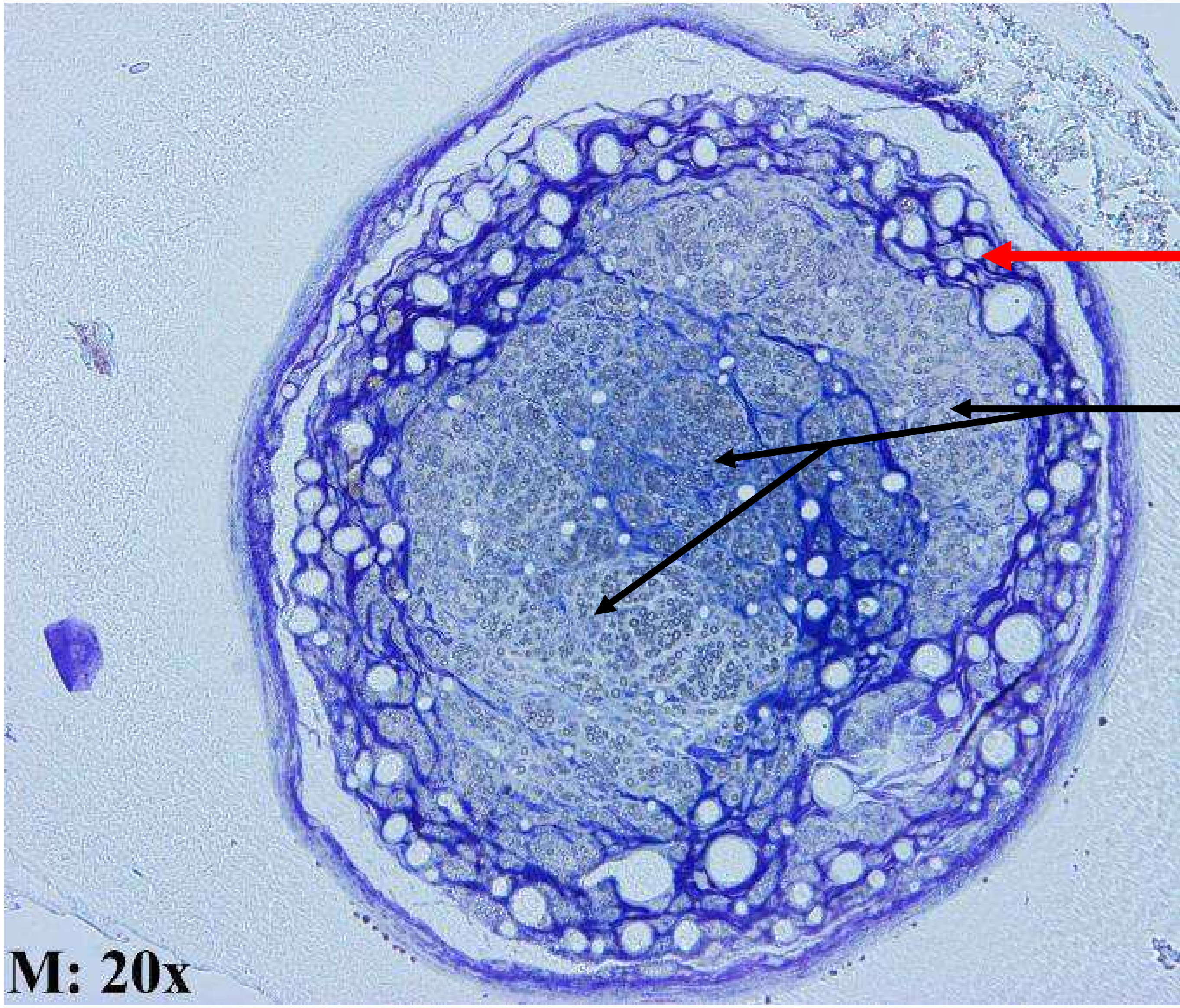




(C) Regeneration in a chamber following nerve excision:



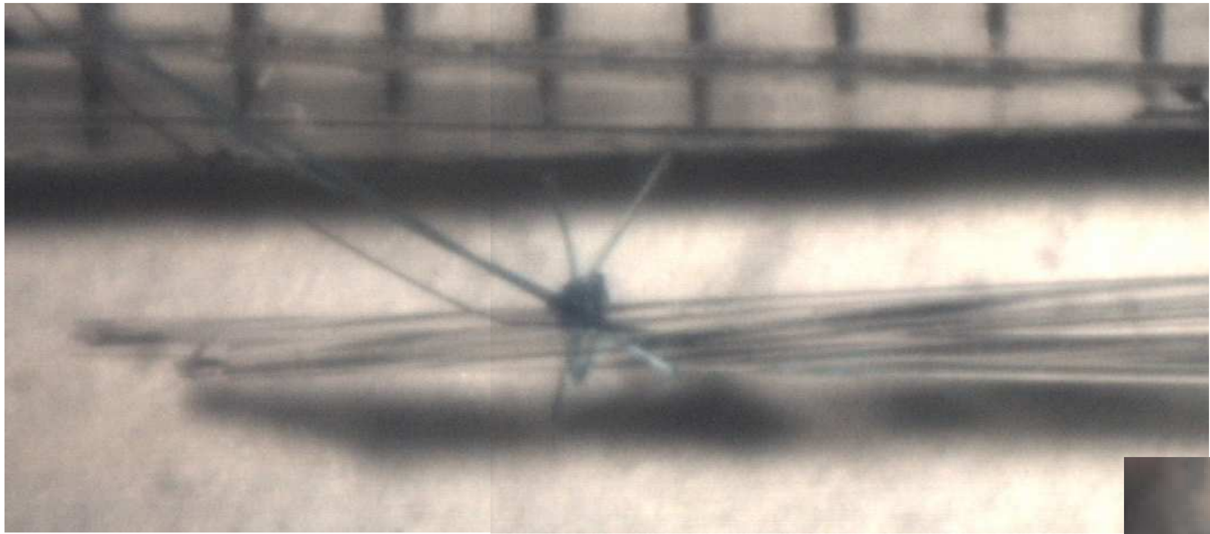
Cross-section of the regenerated nerve (in chamber):



ring of blood vessels

regenerated nerve fibres

First prototype of the artificial synapse:



– **HU 223490 Hungarian patent of Dr. Jeno Pali**

It needs appropriate tissue environment: STEM CELLS!

Some words about the stem cells…..

<u>Definition</u>: A stem cell owns the ability to duplicate itself into a stem cell + another cell which can be either a stem cell or a differentiating cell.

$$\mathbf{A} = \mathbf{A} + \mathbf{A}$$

or

$$\mathbf{A} = \mathbf{A} + \underline{\mathbf{B}}$$

Types of stem cells:

– embrionic
– fetal
– amniotic membrane
– umbilical cord
– umbilical cord blood
– bone marrow
– peripheral blood
– retinal pigment epithelial
– rejuvenated fibroblast
– ((skin, intestines, corneo-scleral, olfactory bulb, respiratory system, adipose tissue, G-null resting))

The following diseases can be treated with stem cell therapy currently:

- Diabetic foot
- Heart muscle after heart attack
- Multiple sclerosis
- Spinocerebellar ataxia
- Epilepsy
- SMA
- Optic nerve atrophy
- Cerebral palsy
- Perinatal hypoxygenic brain damage
- Partial spinal cord injury

Future: **making entire body parts from stem cells!**

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4., **3-dimensional measuring, movement analyzing and modelling system**

3-dimensional measuring, movement analyzing and modelling system:

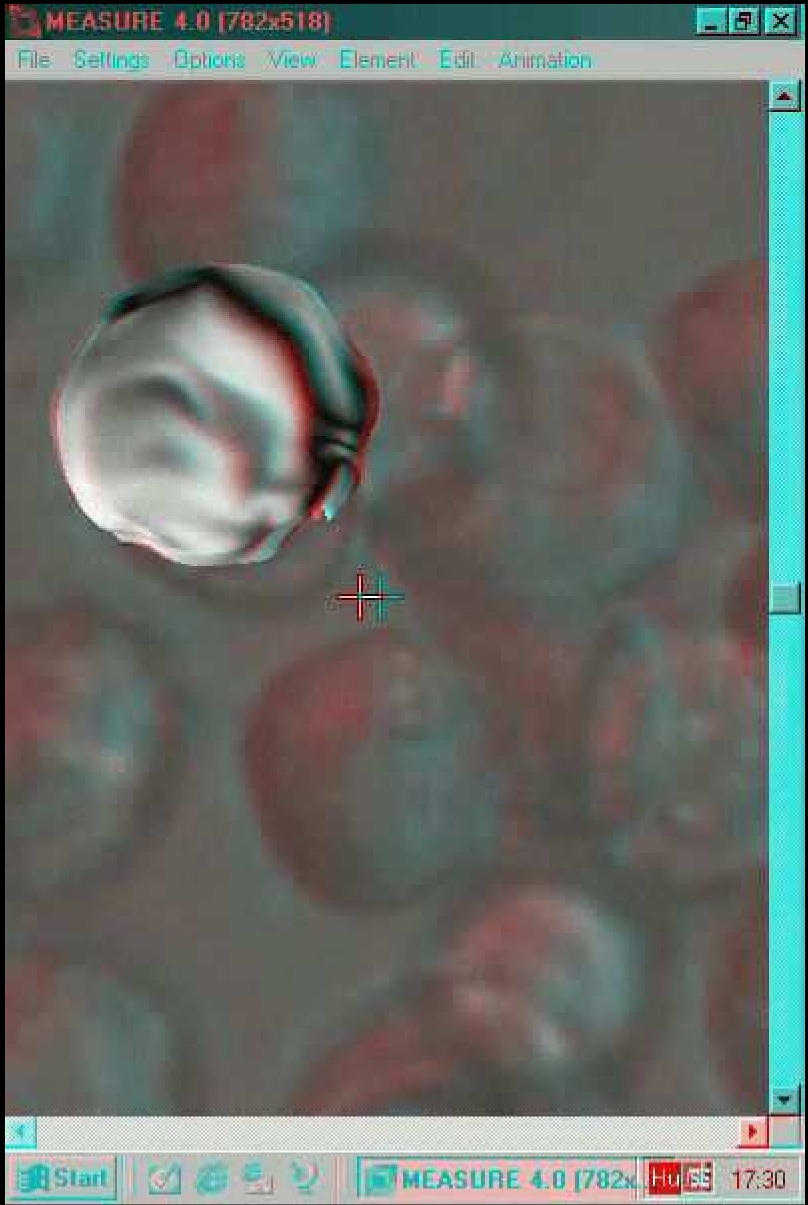
The research team under the leadership of my fellow-worker **Dr. Istvan Stuber** (*Laboratory of Three-dimensional Morphology and Movement Analysis* on the Faculty of Physical Education and Sports Sciences of the Semmelweis Medical University, Budapest, Hungary) has developed a wide network of innovative methods and equipment for scientific investigation that originates the facilities of

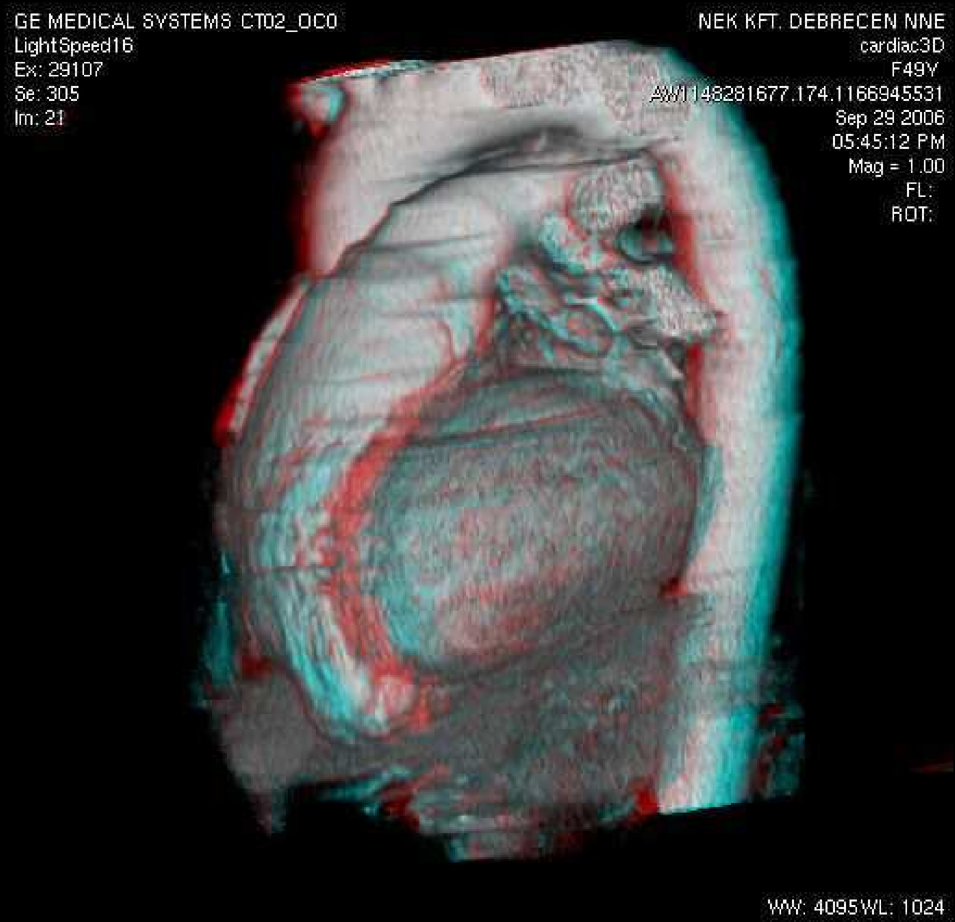
a.) true three-dimensional visualisation of both microscopic and macroscopic objects under optical conditions as it was impossible until know;

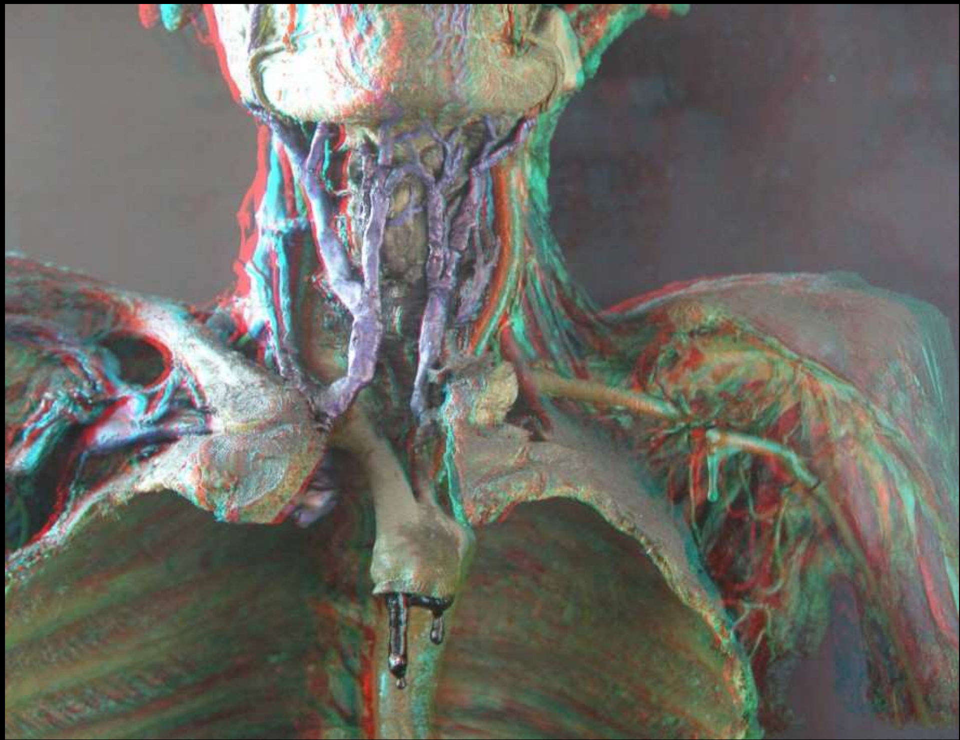
b.) performing detailed three-dimensional measurement, mathematical analysis and modelling of their structure;

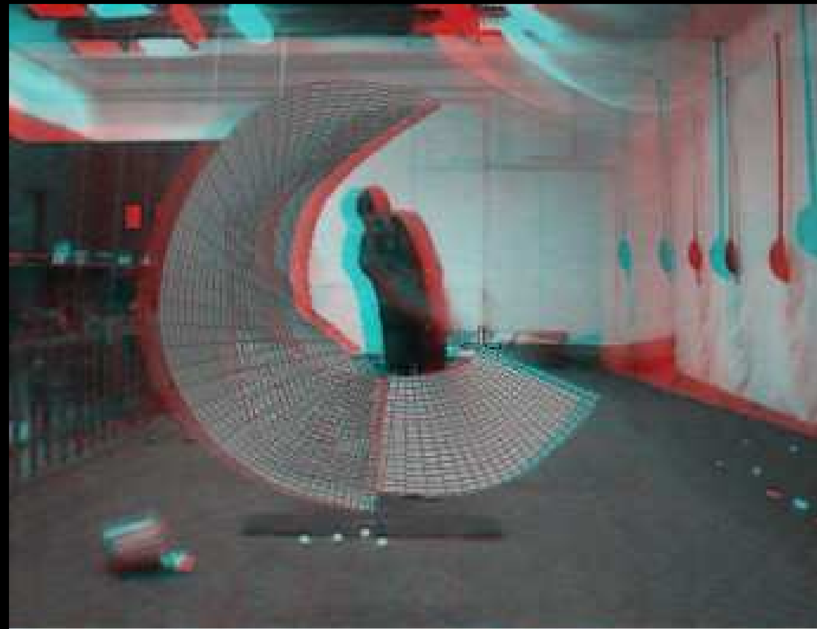
c.) measuring and analysis of the movements of them in space.

Please, wear red-blue glasses to observe the following anaglyph pictures in true 3D:









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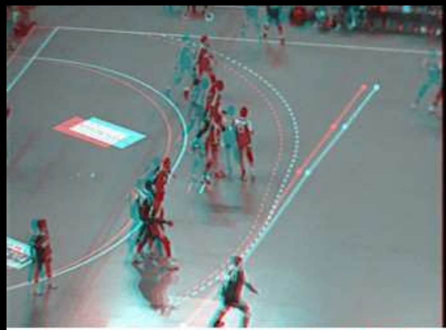

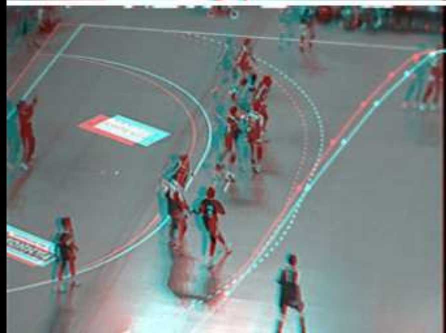

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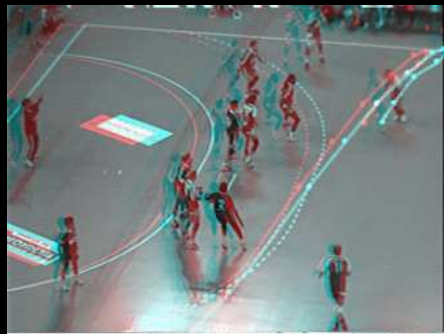

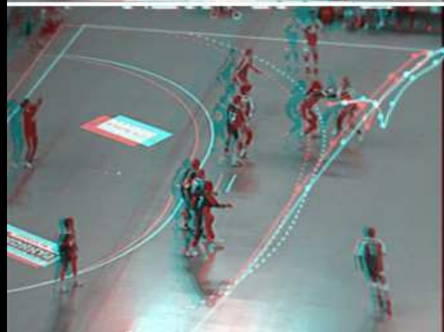

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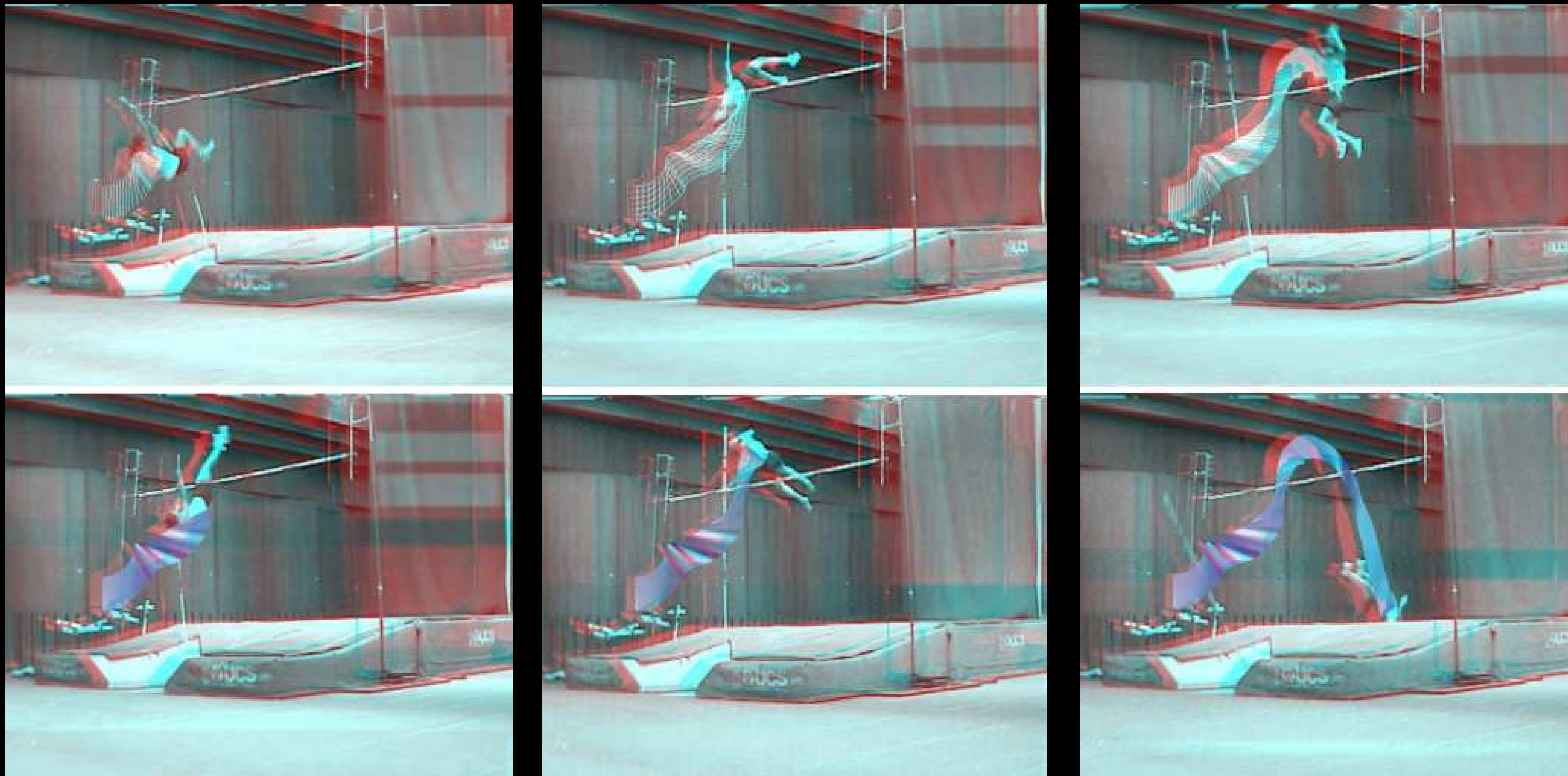

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Some special lectures on this theme….

Dr. Jeno Pali's lecture on
'Integration of sensory and motor devices with the human body: the neuroprosthesis'
in the
Hungarian Parliament
in year 2006.

Dr. Jeno Pali's lecture on
'Integration of sensory and motor devices with the human body: the neuroprosthesis'
in Pune, India, 2007.

Contact: Dr. Jeno Pali, Ph.D.
infocityhungary@gmail.com