

Thermomechanobiology: the next frontier for treating osteoarthritis

Dominique P. Pioletti

Laboratory of Biomechanical Orthopedics
Institute of Bioengineering
EPF-Lausanne
(lbo.epfl.ch)

EPFL

Musculoskeletal conditions

WHO (February 2021):

- Approximately 1.71 billion people have musculoskeletal conditions worldwide.
- Musculoskeletal conditions are the leading contributor to disability worldwide

Musculoskeletal conditions include:

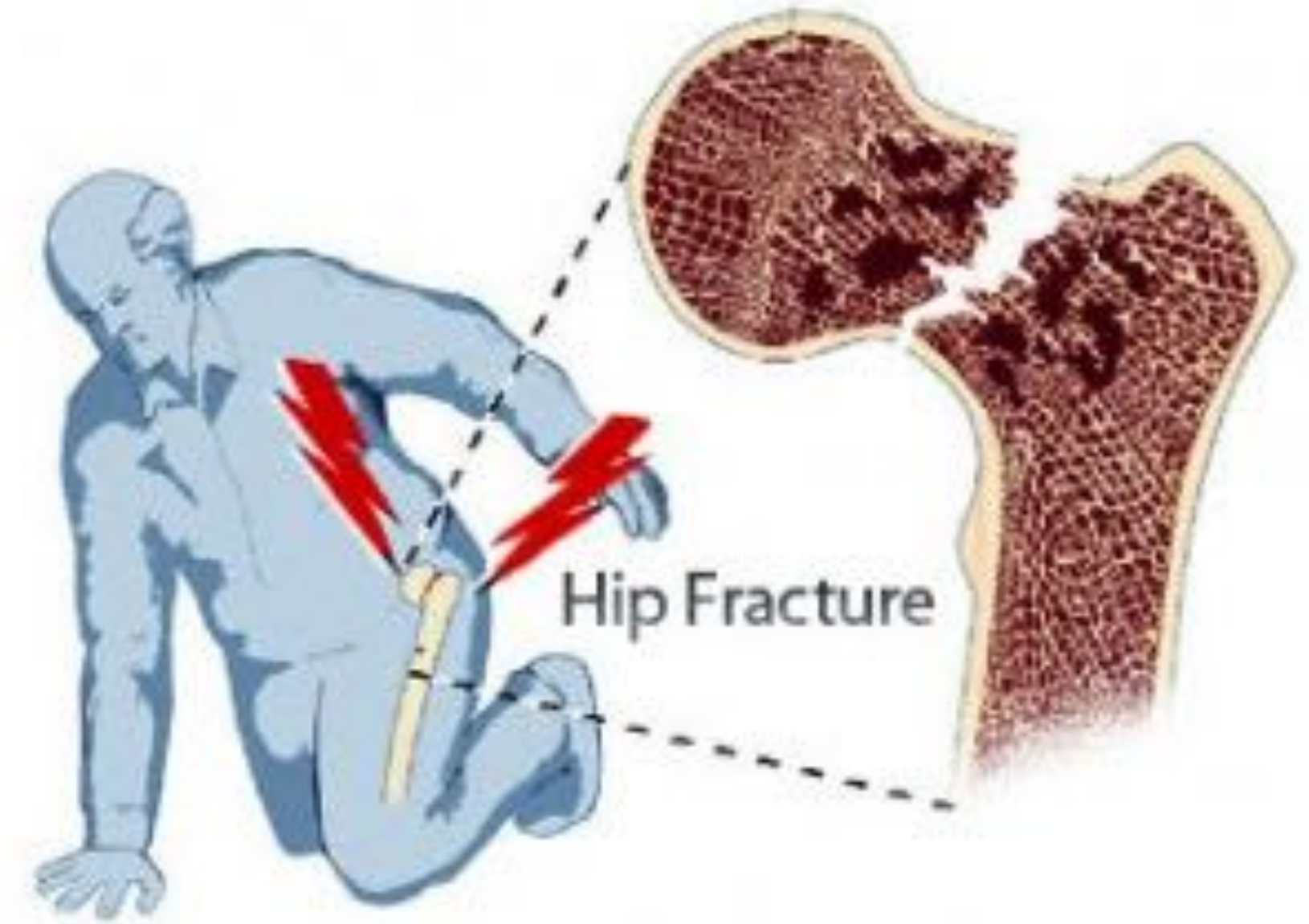
- Osteoarthritis
- Osteoporosis, osteopenia and associated fragility fractures, traumatic fractures of soft and hard tissues

All age groups of the population are affected

Biomechanical aspects are involved in most musculoskeletal conditions



250'000 ACL injuries occur in the USA annually.

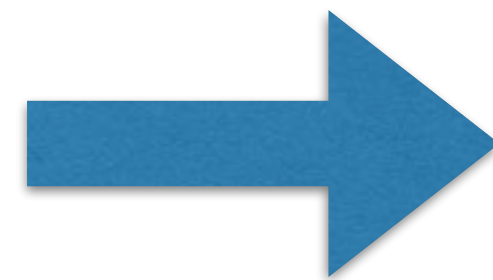


Mortality rate is 20% within 1 year.

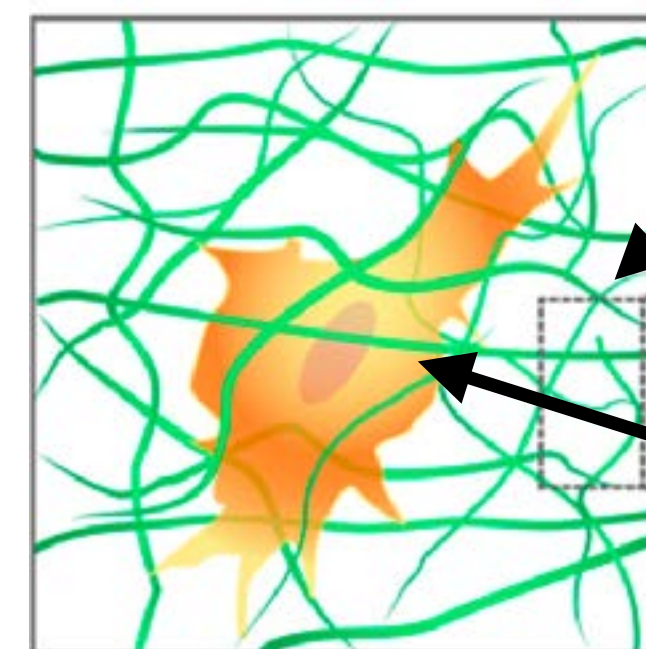
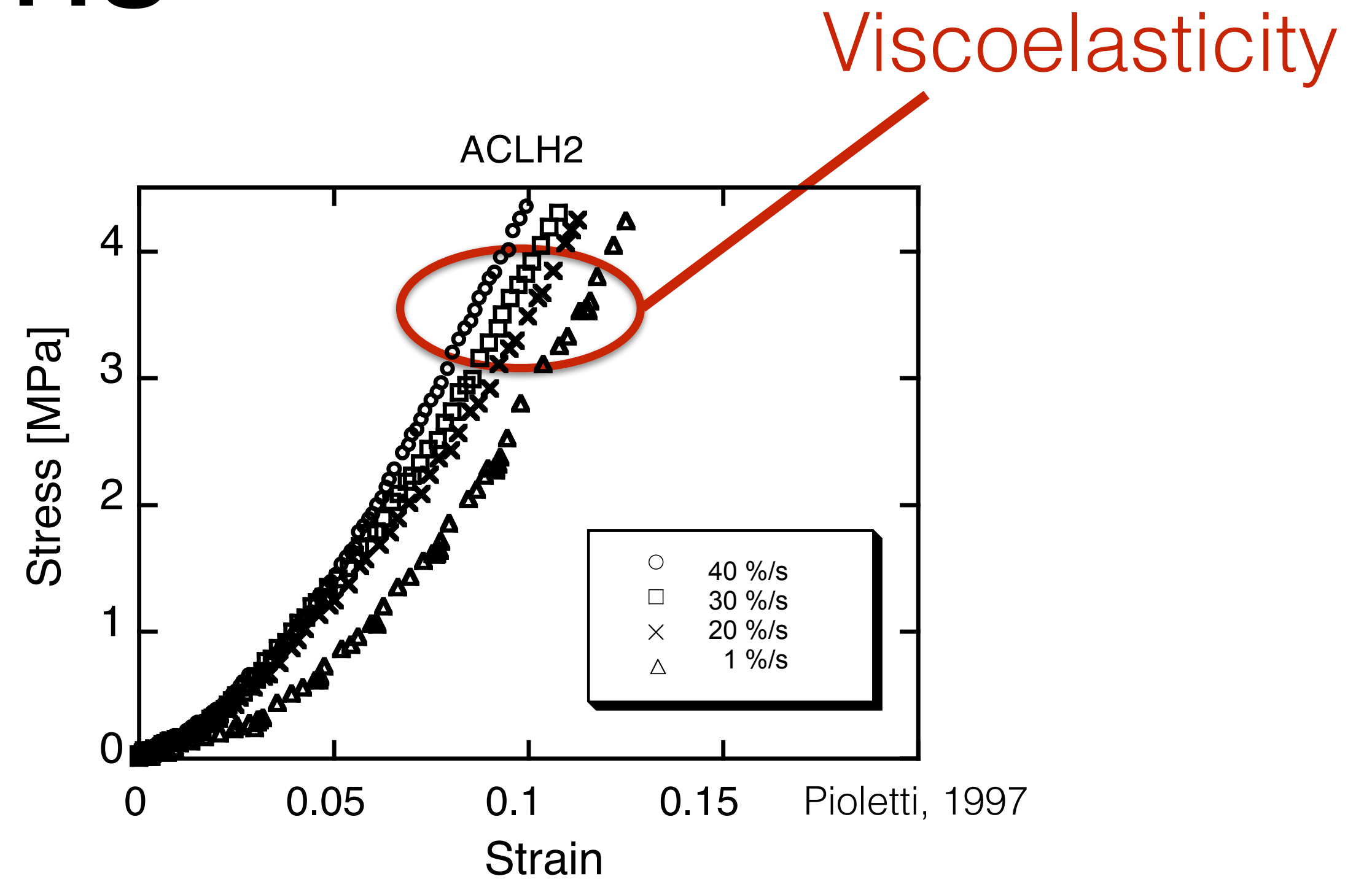
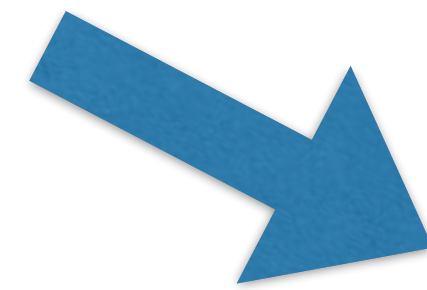
Biomechanical aspects are involved in most musculoskeletal conditions



Mechanical



Biological

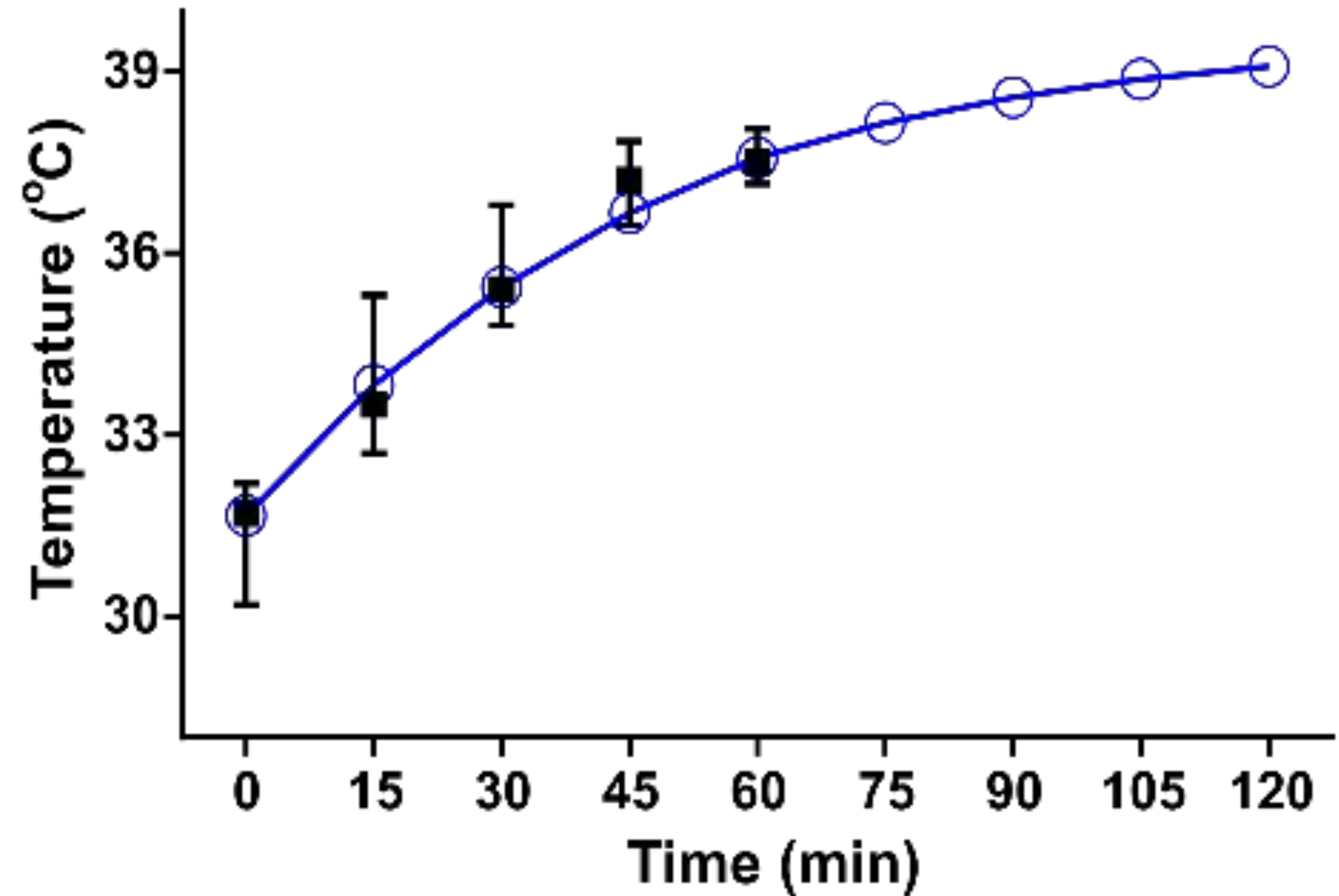
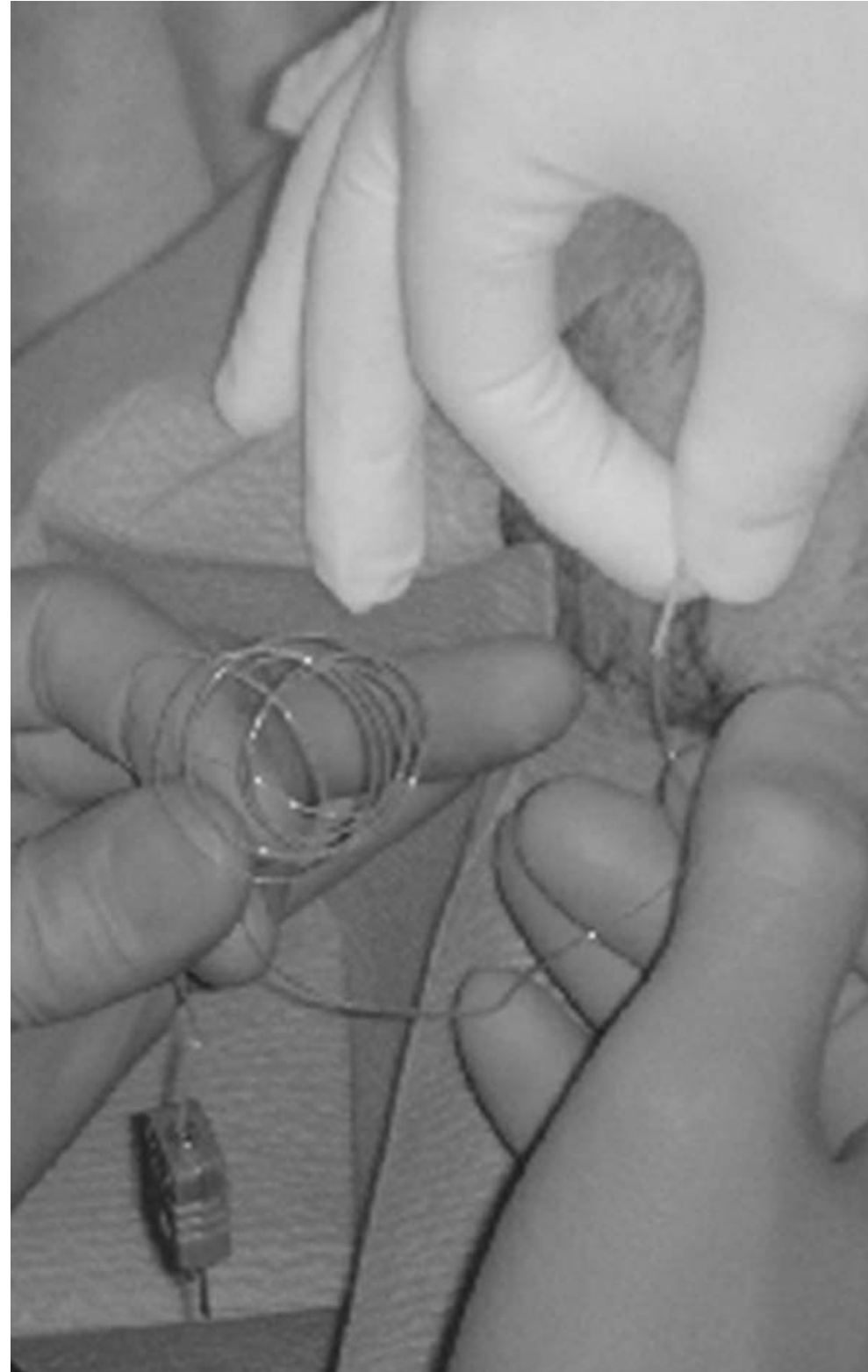


Extra cellular
matrix (ECM)

Cell

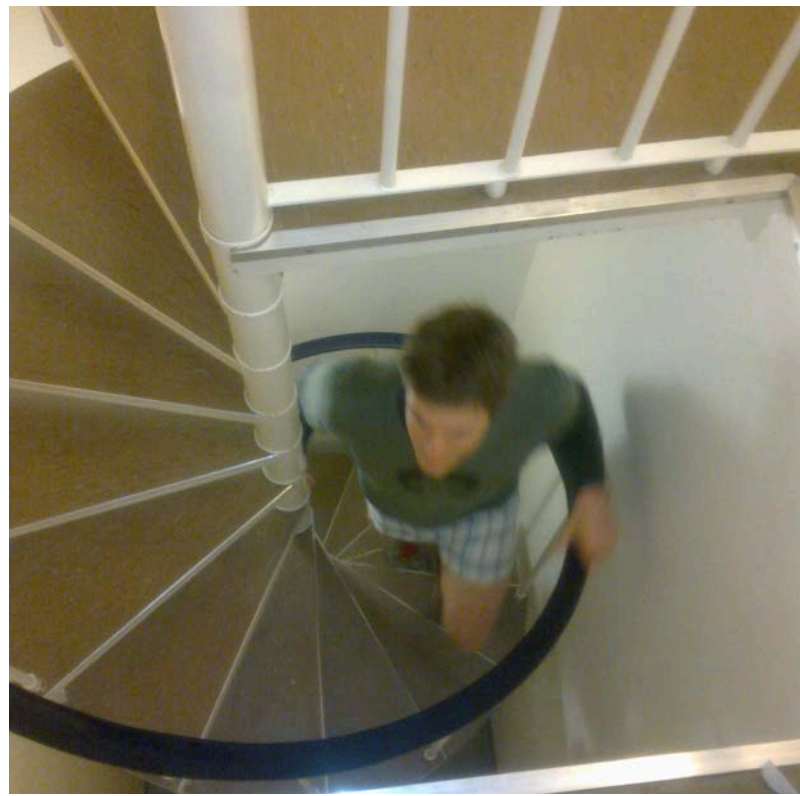
?

Under **dynamical** mechanical loading, **knee** temperature with healthy cartilage is **not** constant

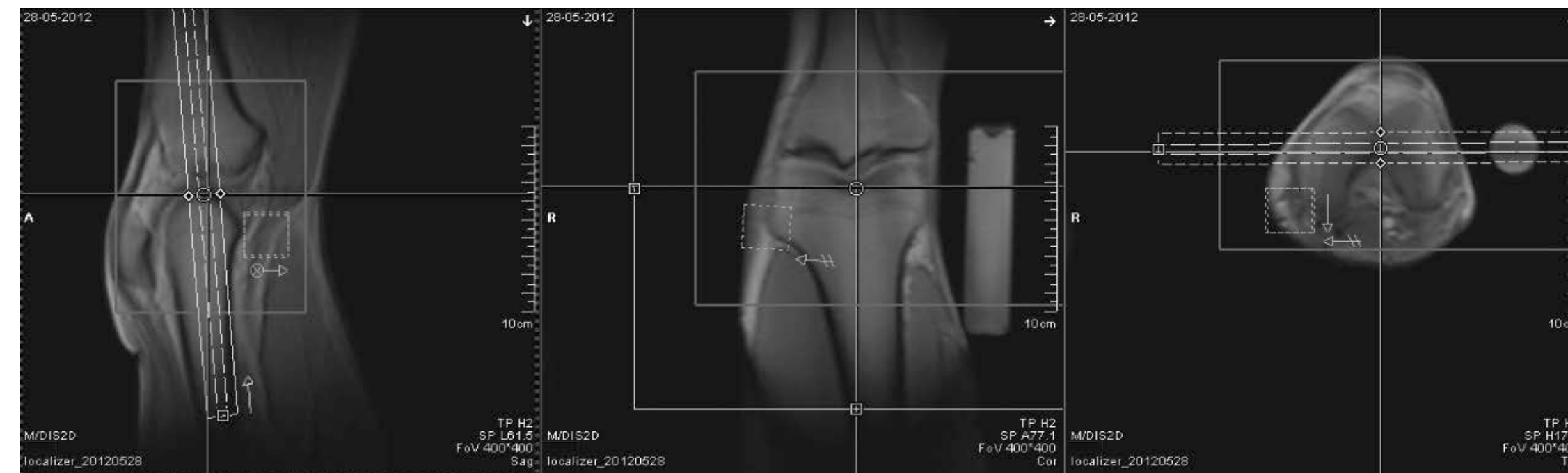


Under **dynamical** mechanical loading, the temperature in healthy **cartilage** is **not** constant

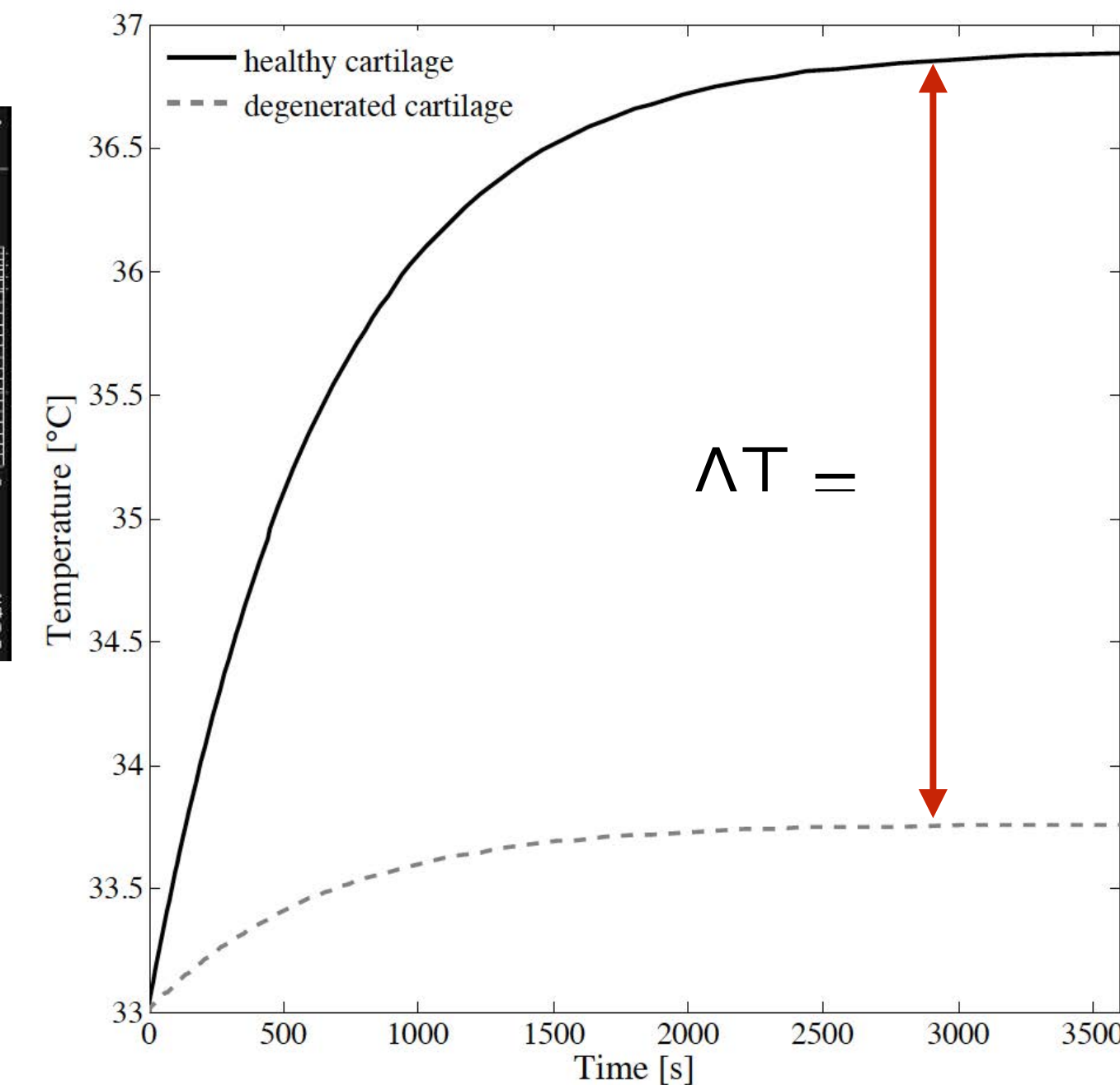
3-T clinical scanner (Siemens)



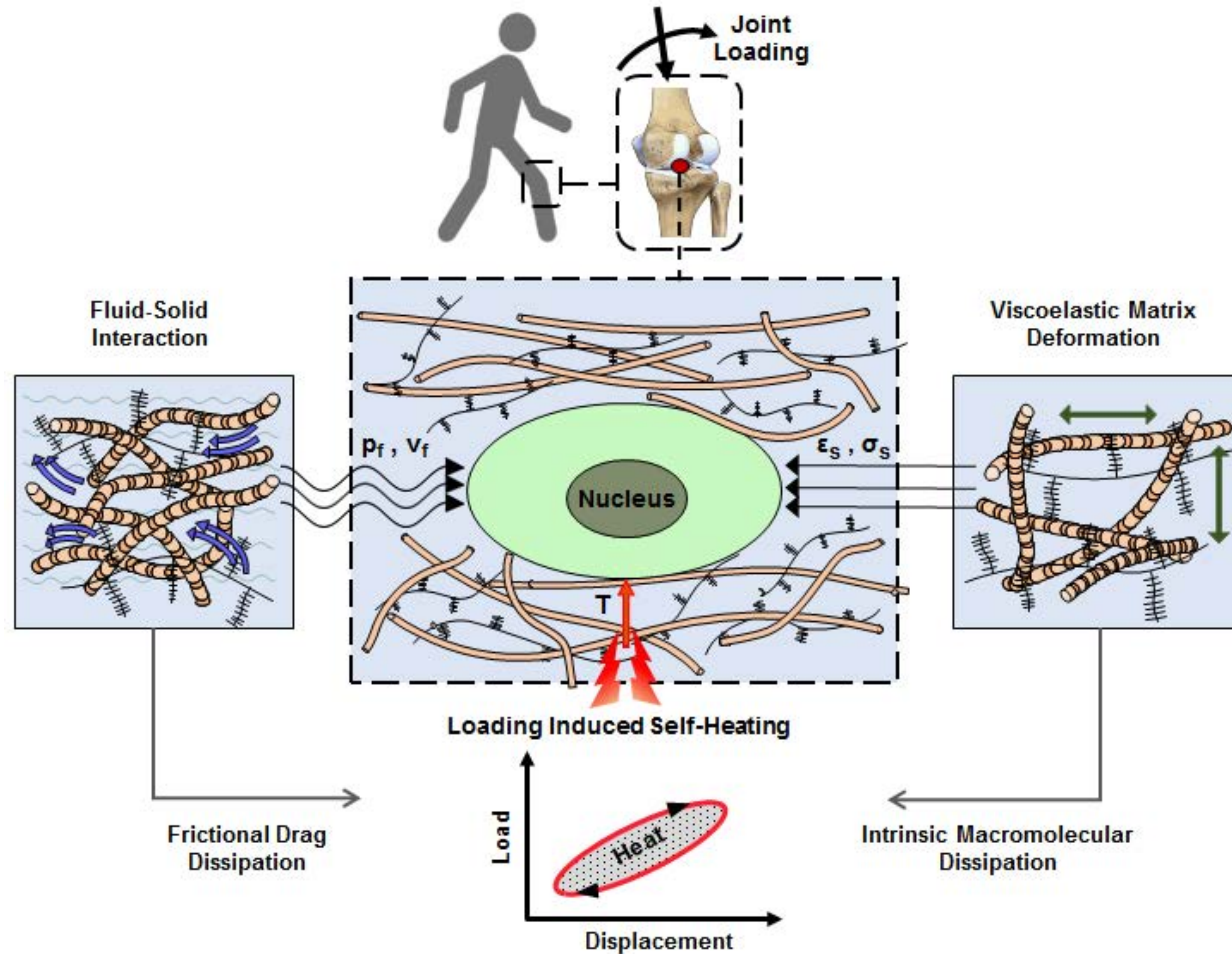
Mechanical stimulation:
400 steps up and down



Proton Resonance Frequency Shift
(PRFS)-based MR thermometry



ECM dissipation -> cartilage tissue



Temperature effect on chondrocytes behaviour

Human epiphyseal chondro-progenitor cells



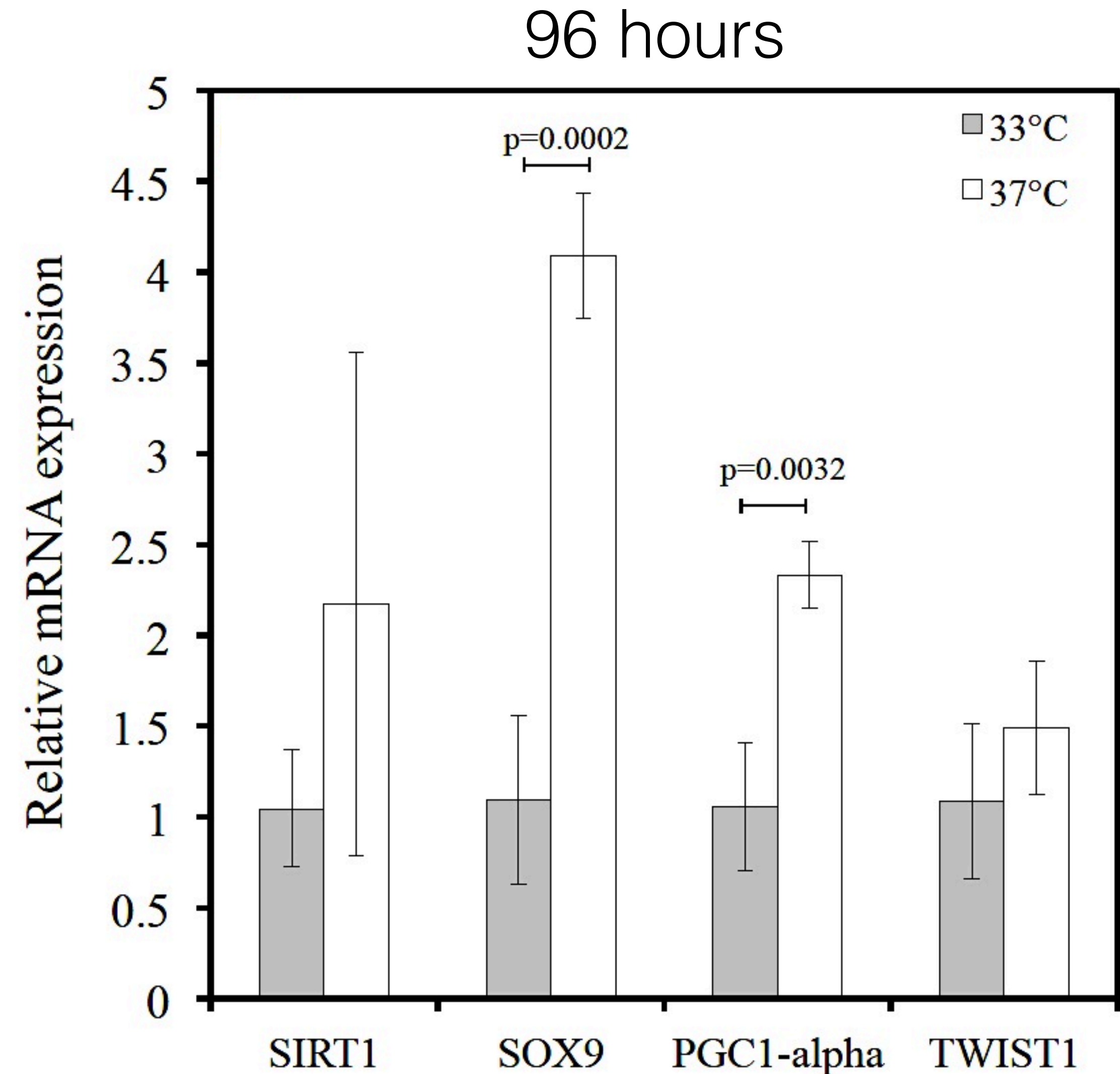
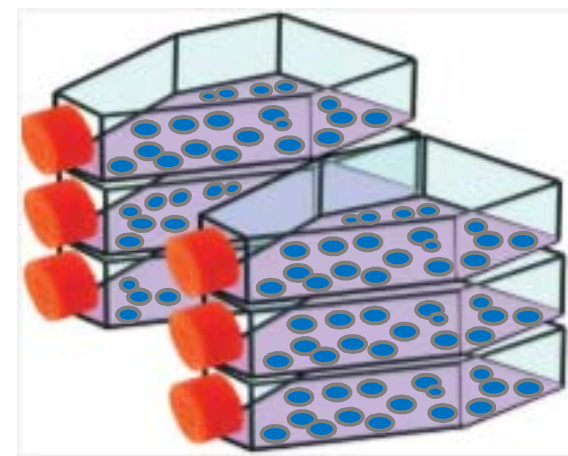
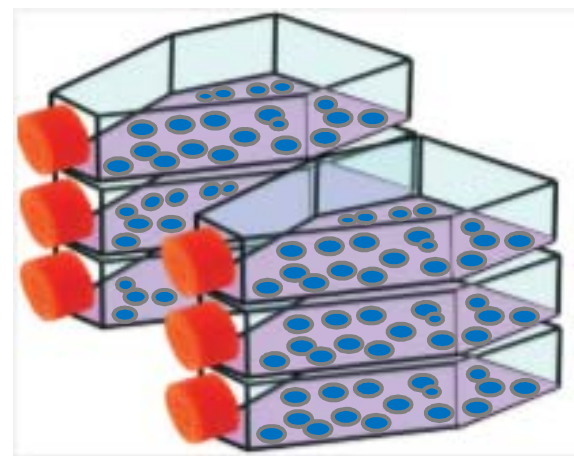
1 single organ donation
(skin cm², cartilage 0.5 cm³, bone 0.5 cm³)

Master Cell Bank
Frozen -165° C

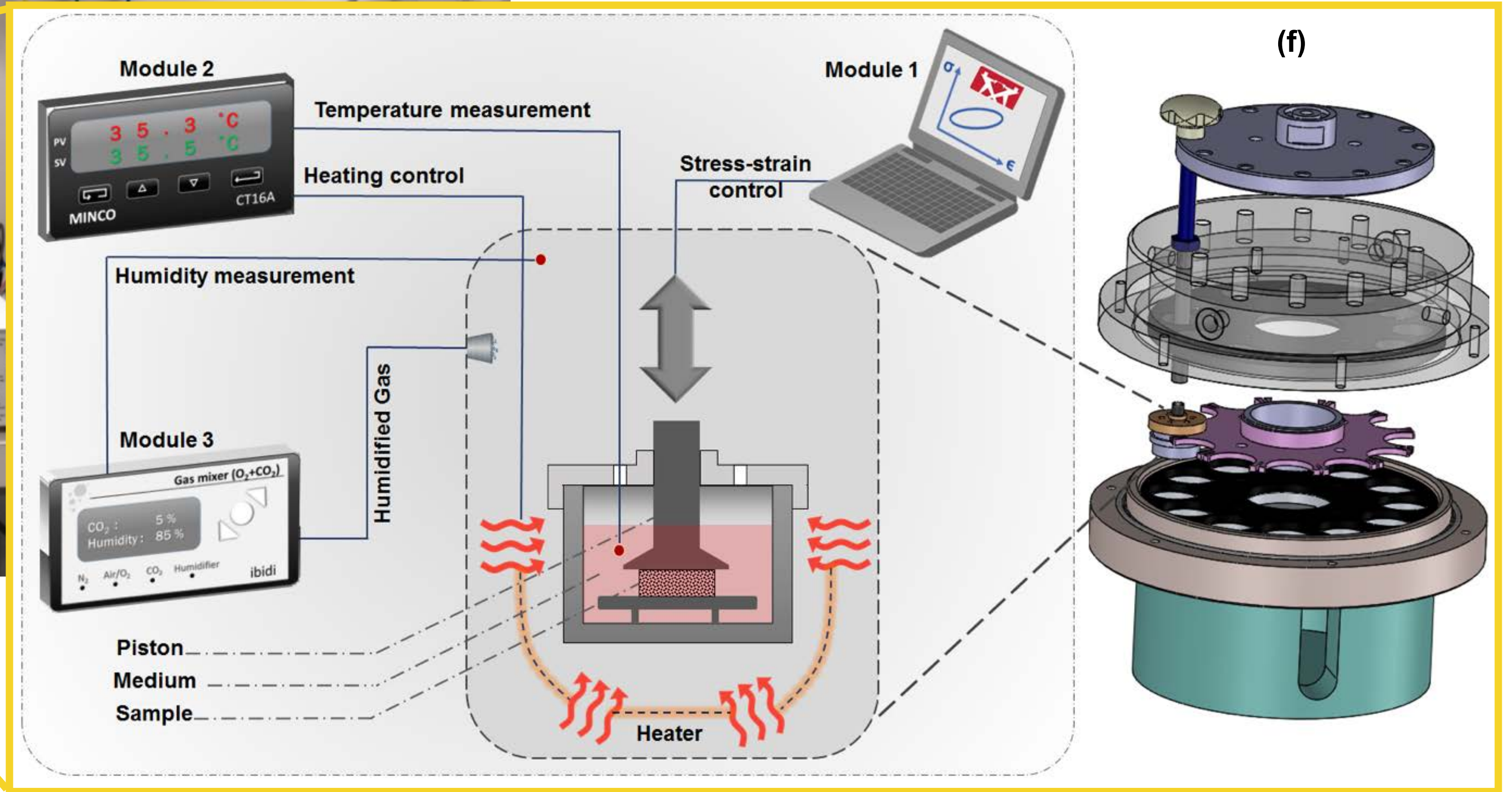
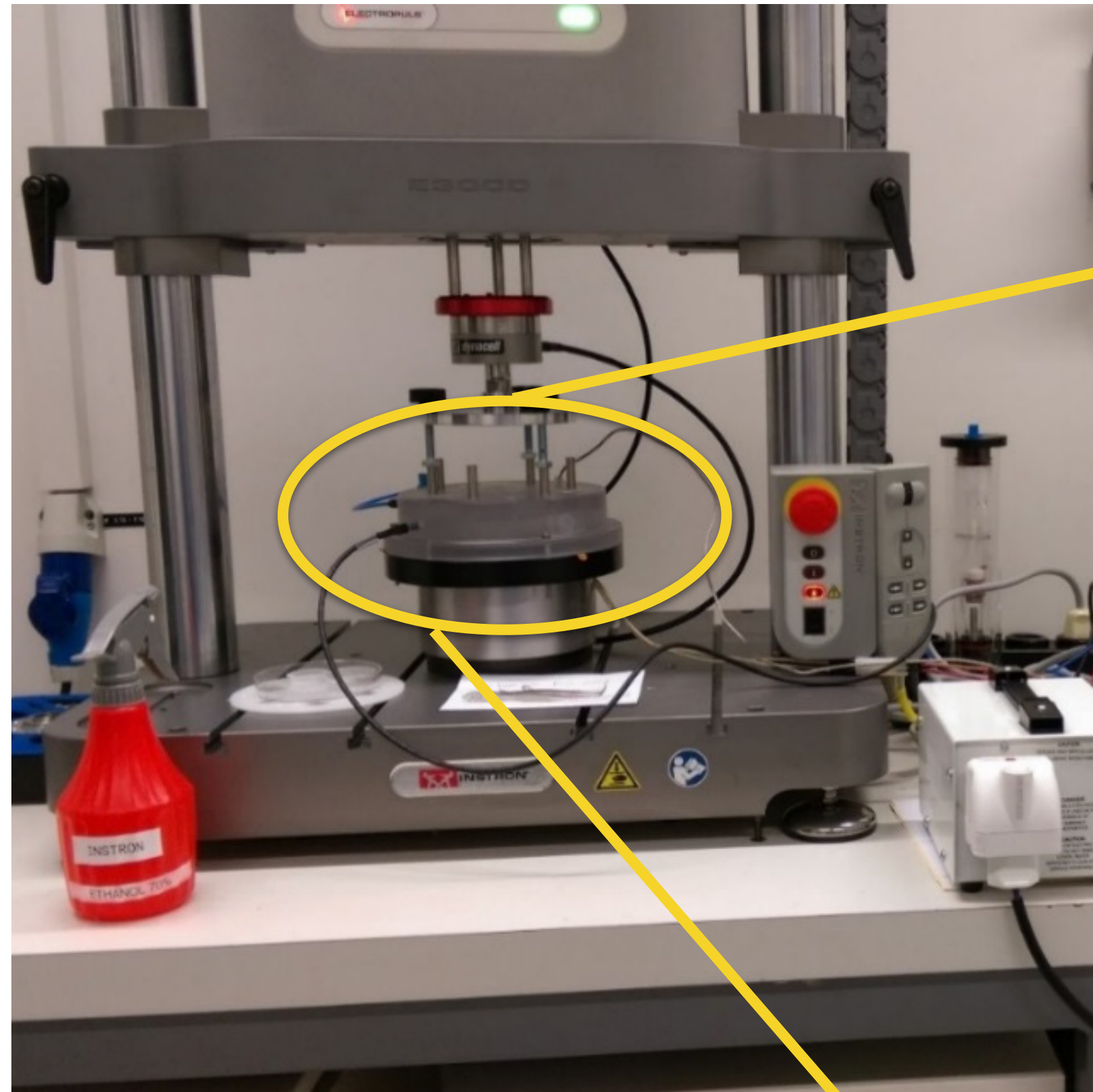


33°C

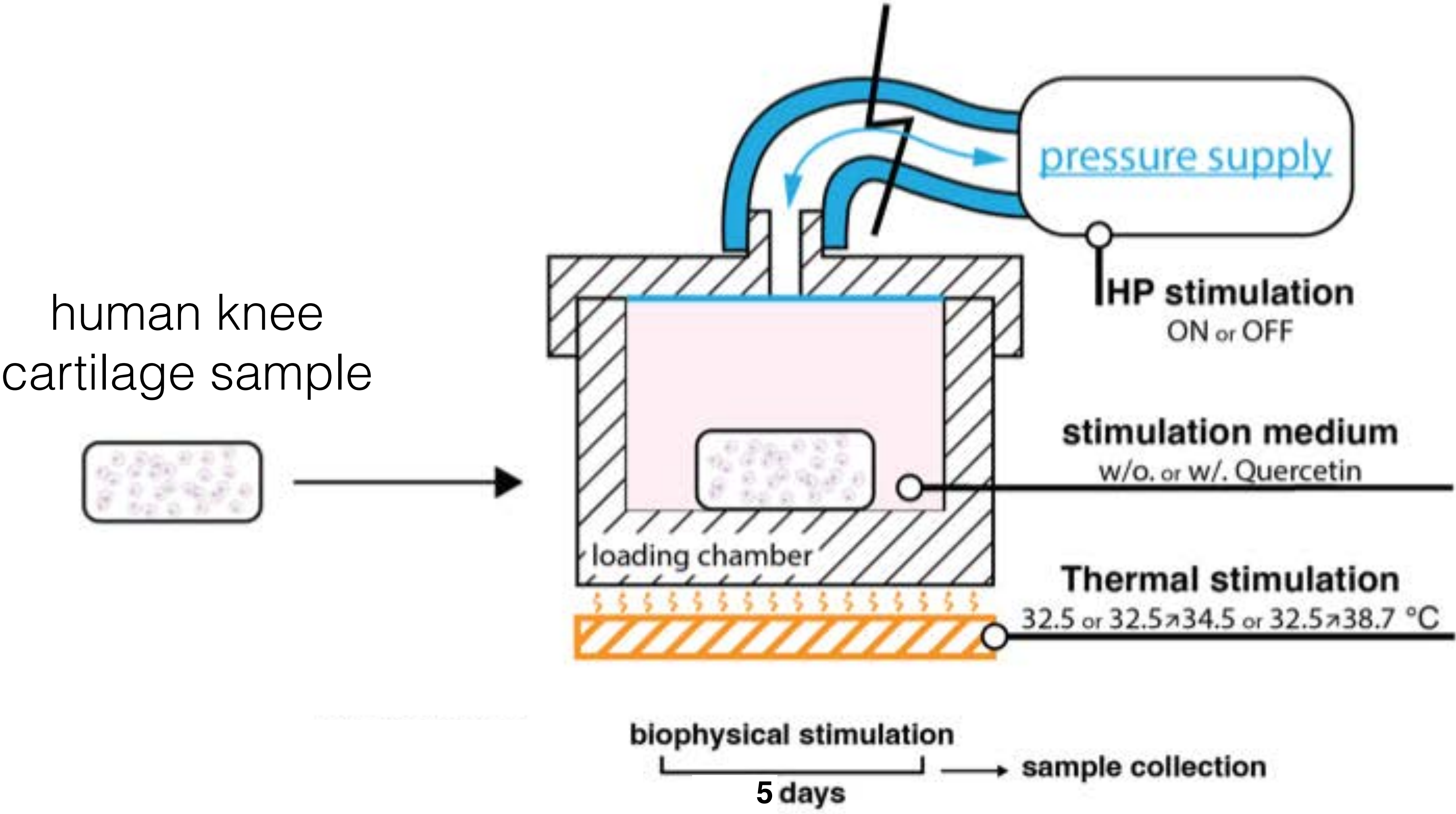
37°C



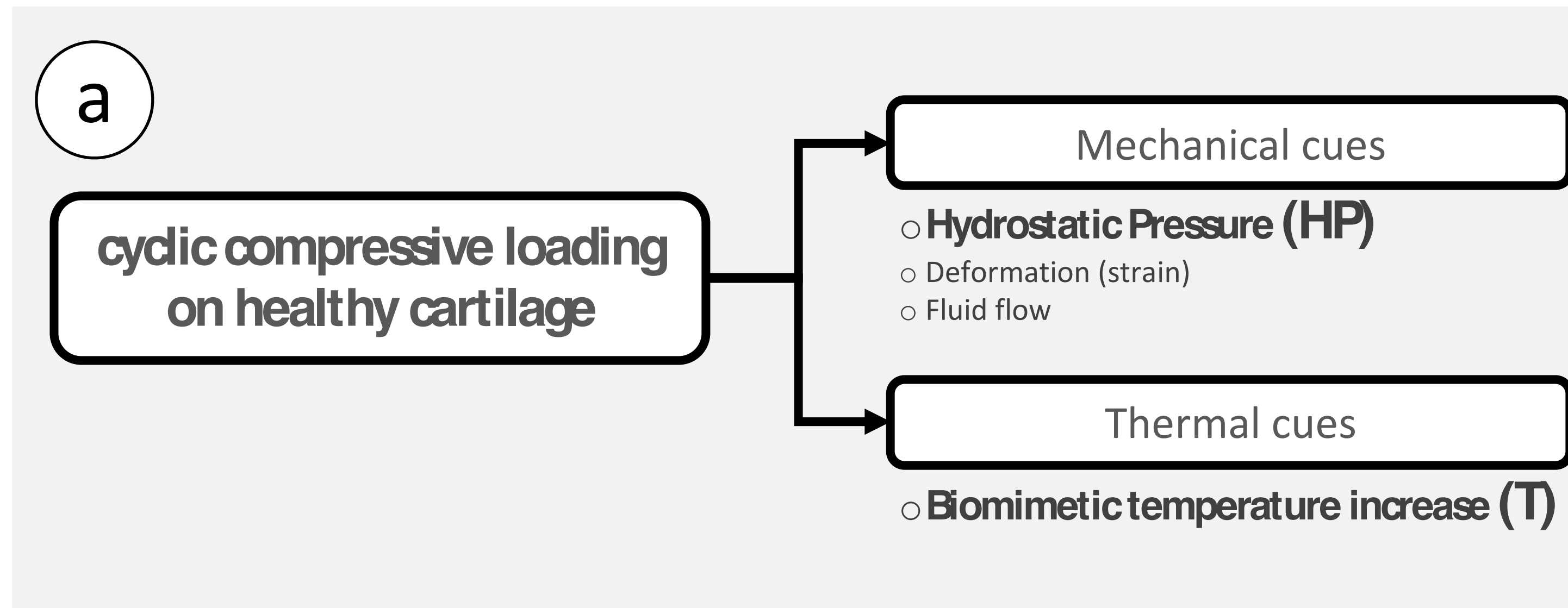
Temperature and gas effects on blood vessel behavior



What's about thermomechanical stimulation at the tissue level?



Research context — from 3 critical points to research questions

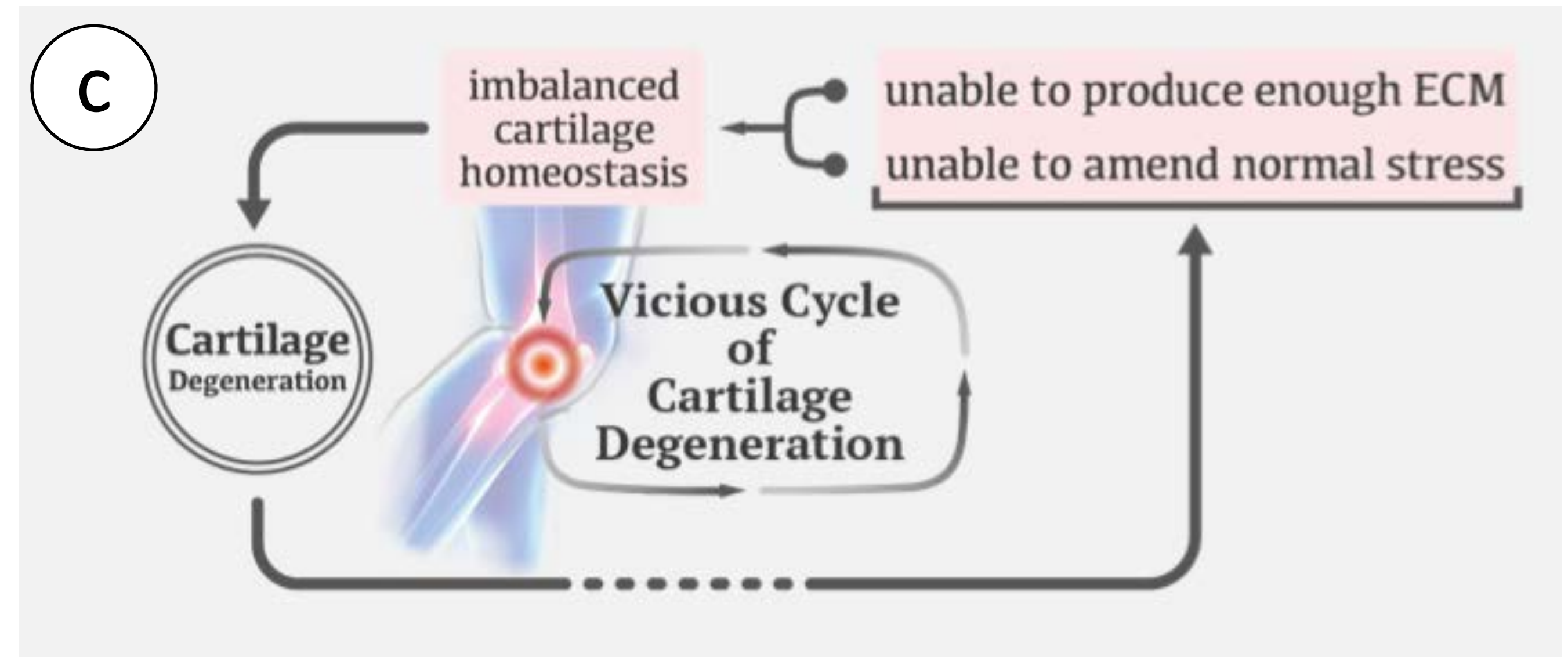
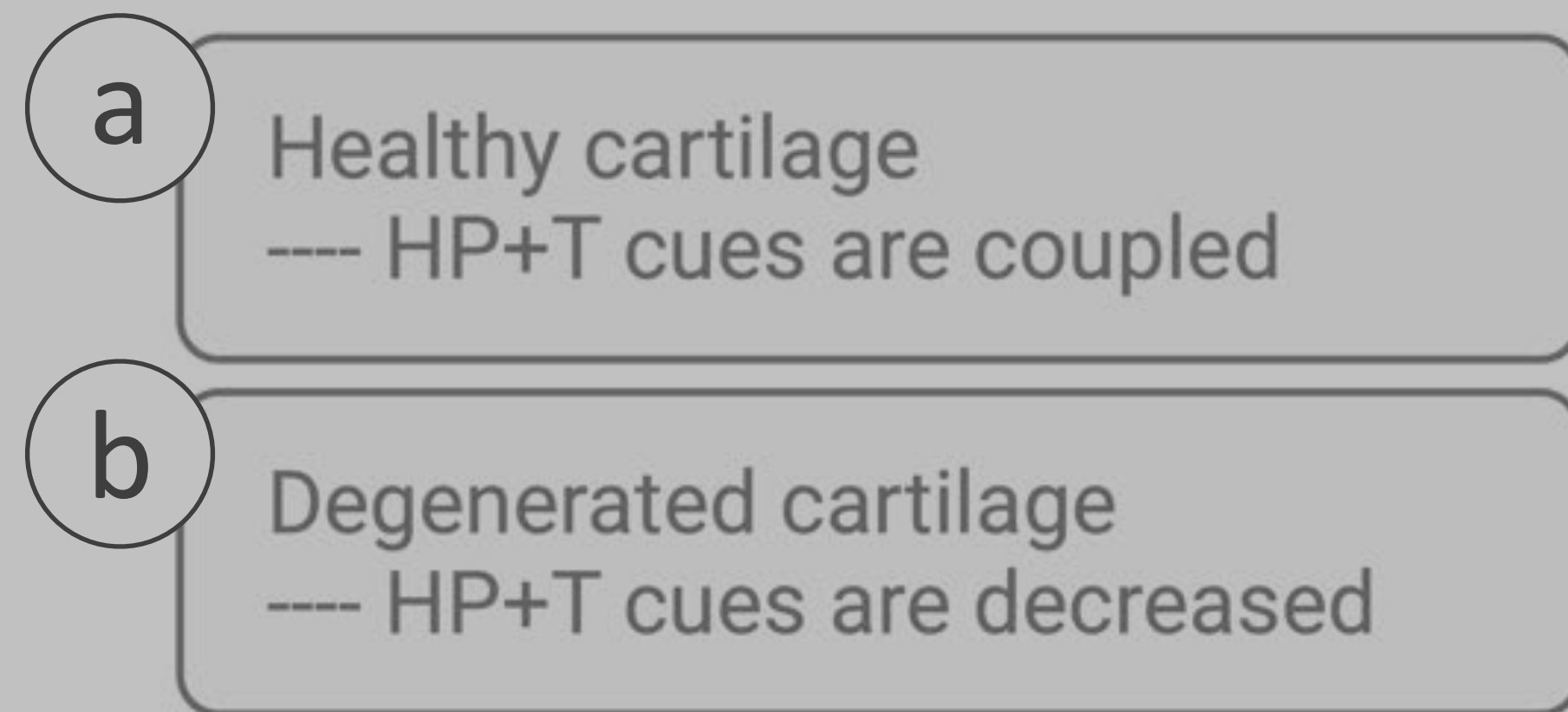


Research context — from 3 critical points to research questions

a Healthy cartilage
---- HP+T cues are coupled

b
in degenerated cartilage
porosity↑ : HP ↓
dissipative property↓ : T_{Max}↓

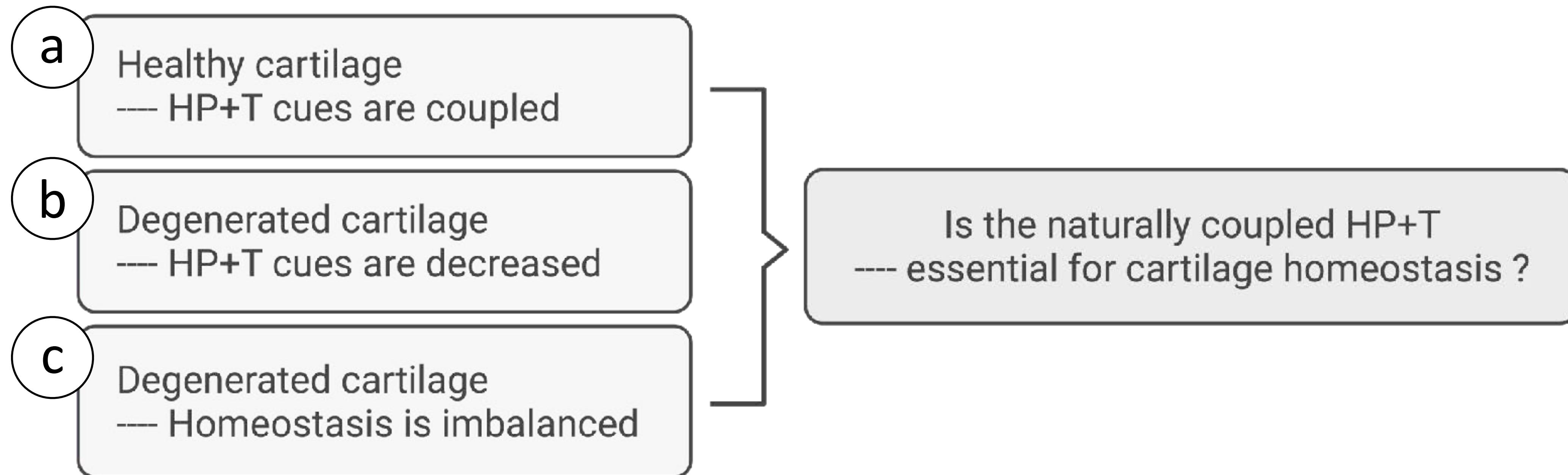
Research context — from 3 critical points to research questions



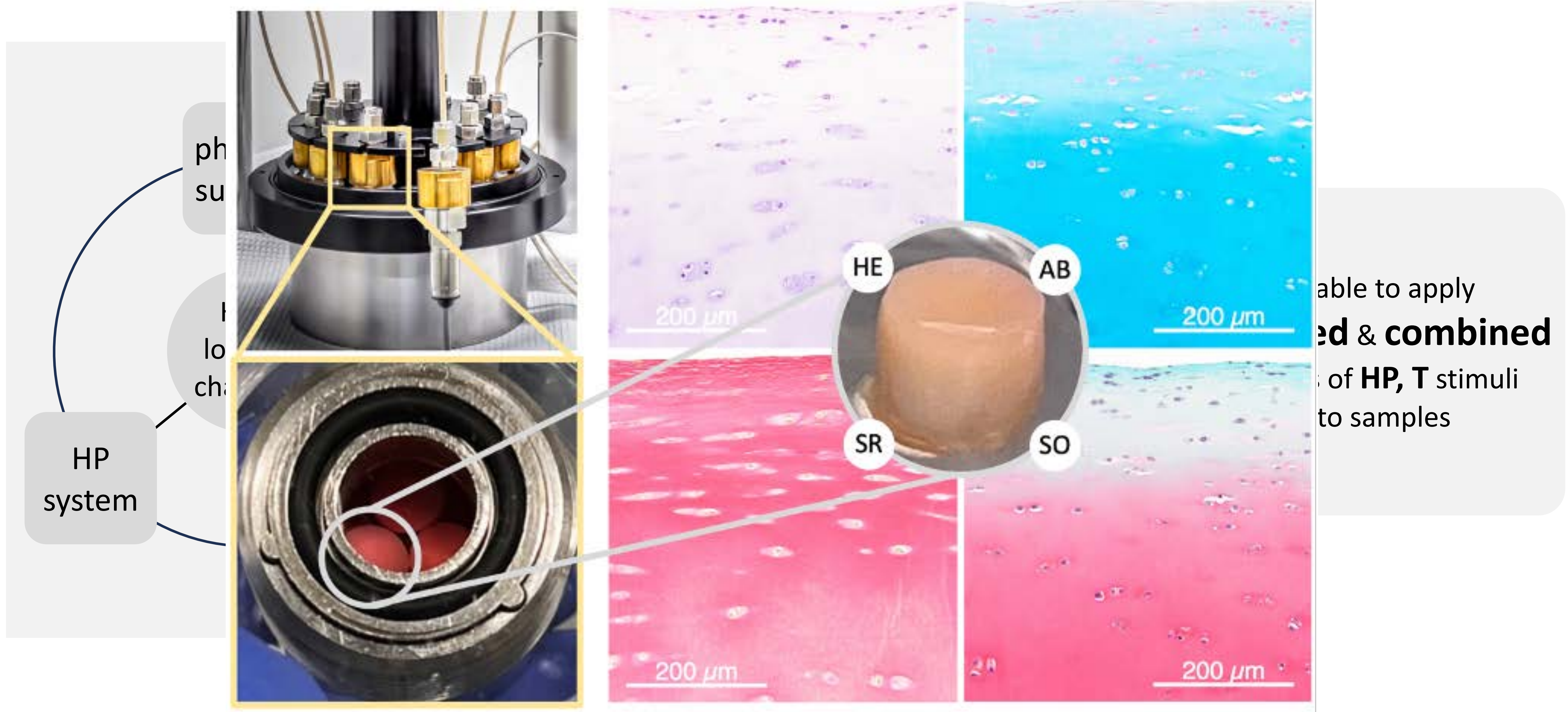
Research context — from 3 critical points to research questions

- a Healthy cartilage
---- HP+T cues are coupled
- b Degenerated cartilage
---- HP+T cues are decreased
- c Degenerated cartilage
---- Homeostasis is imbalanced

Research context — from 3 critical points to research questions

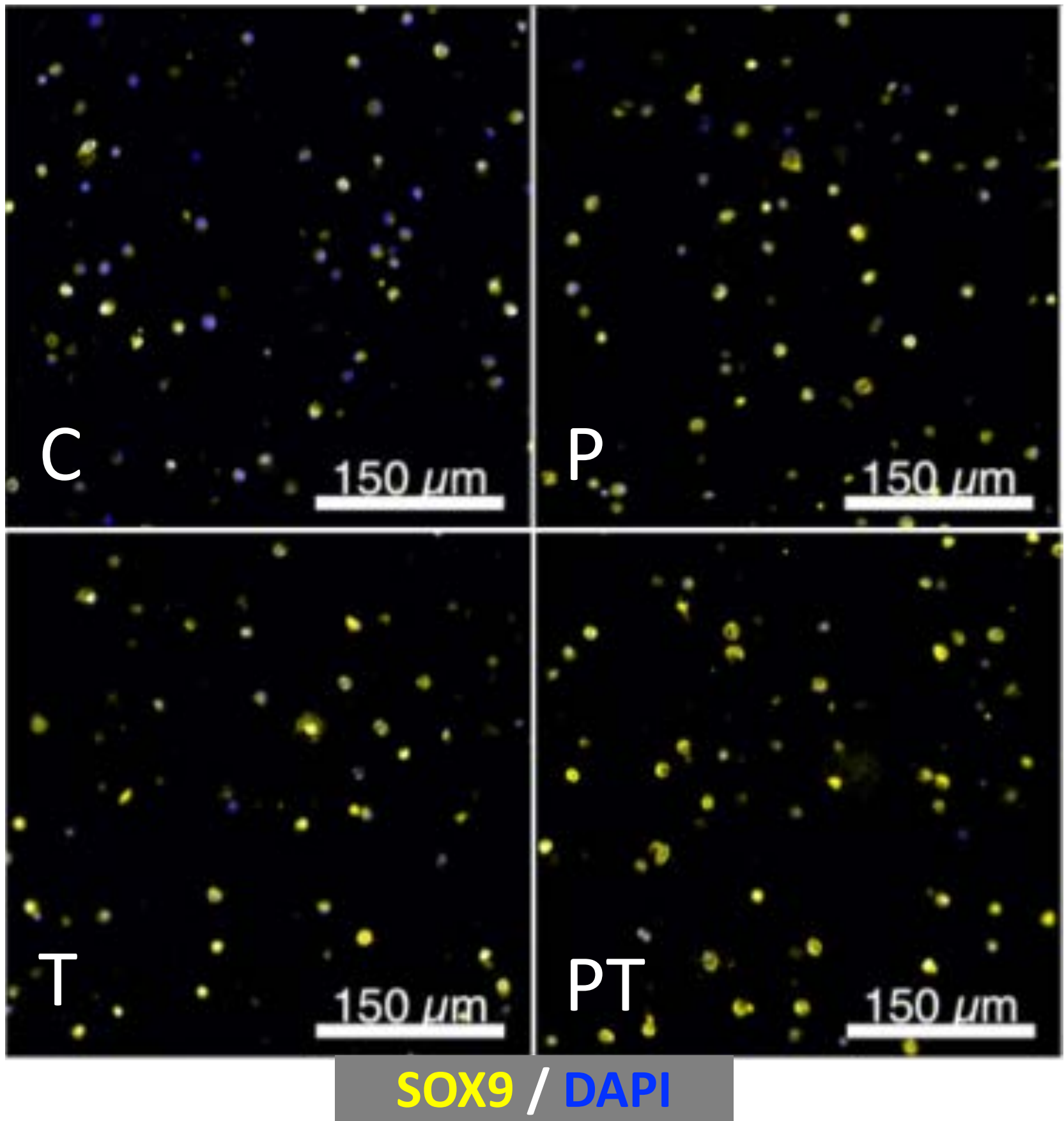
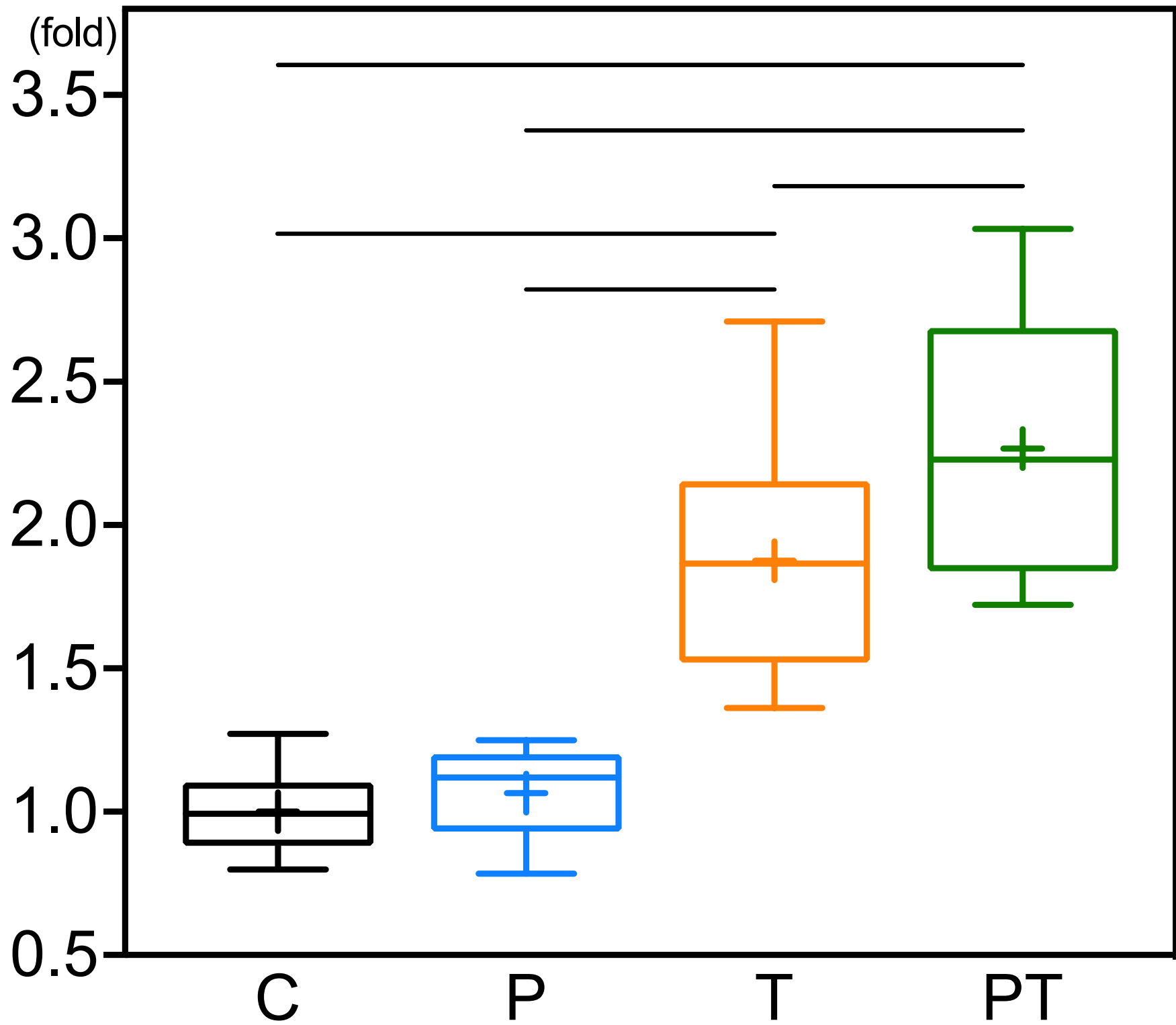


Development of in vitro HP-T platform

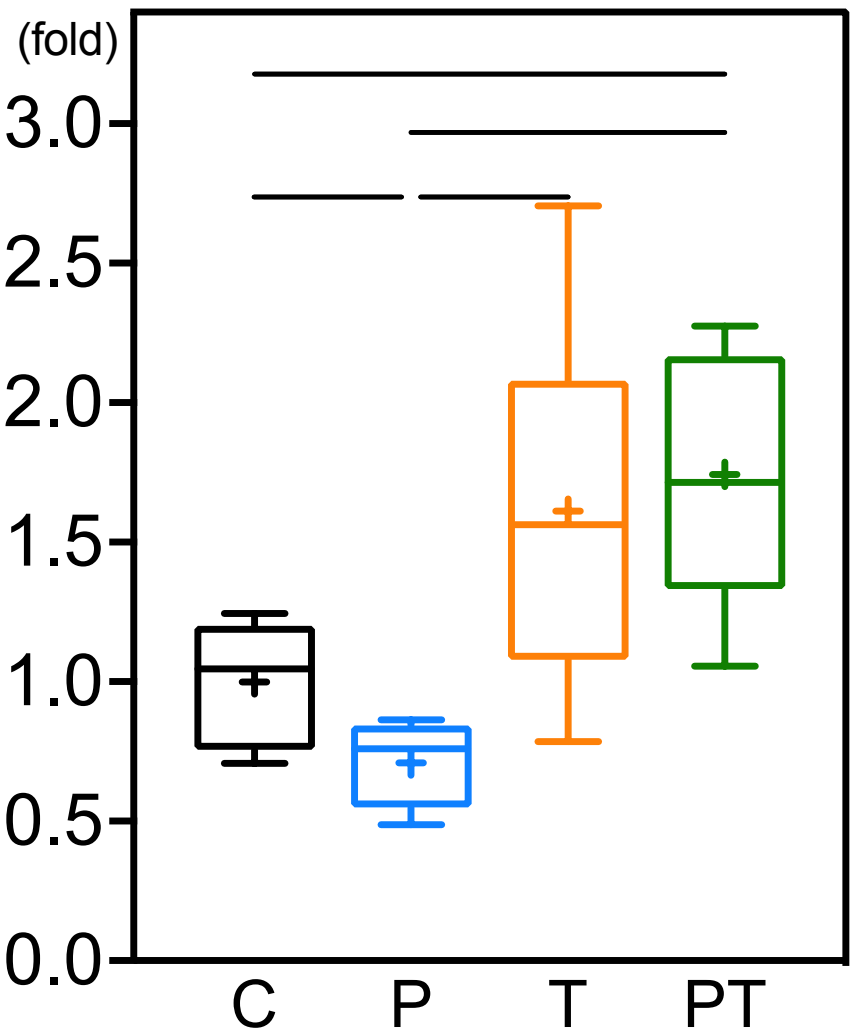


Result 1: Combined HP-T is necessary for maximum **chondroinduction**

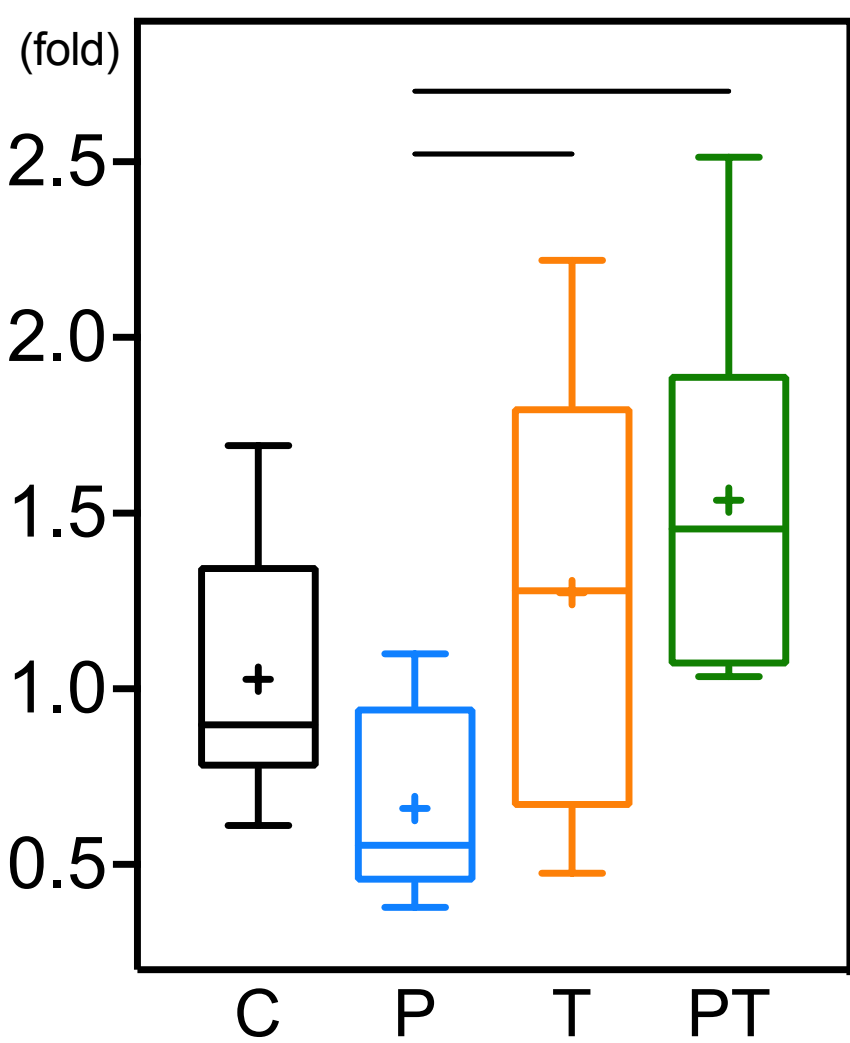
SOX9 / TWIST1



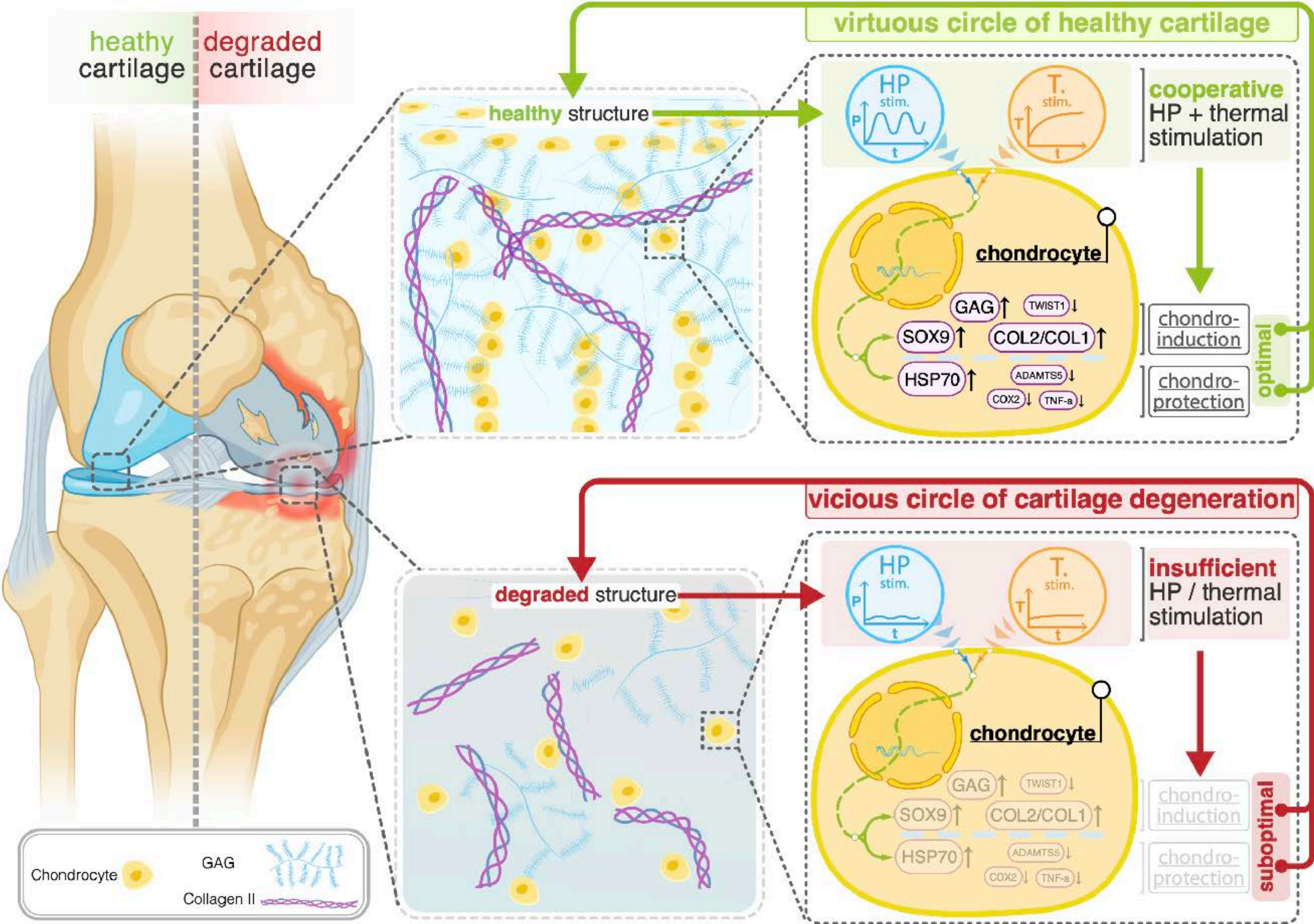
ACAN / ADAMTS5



COL2A / COL1A

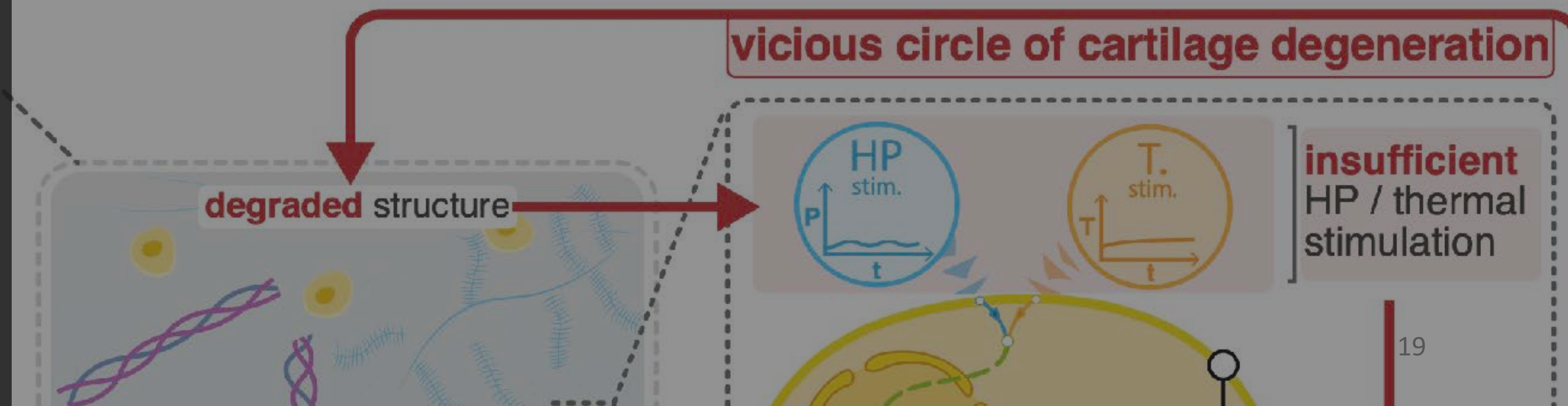
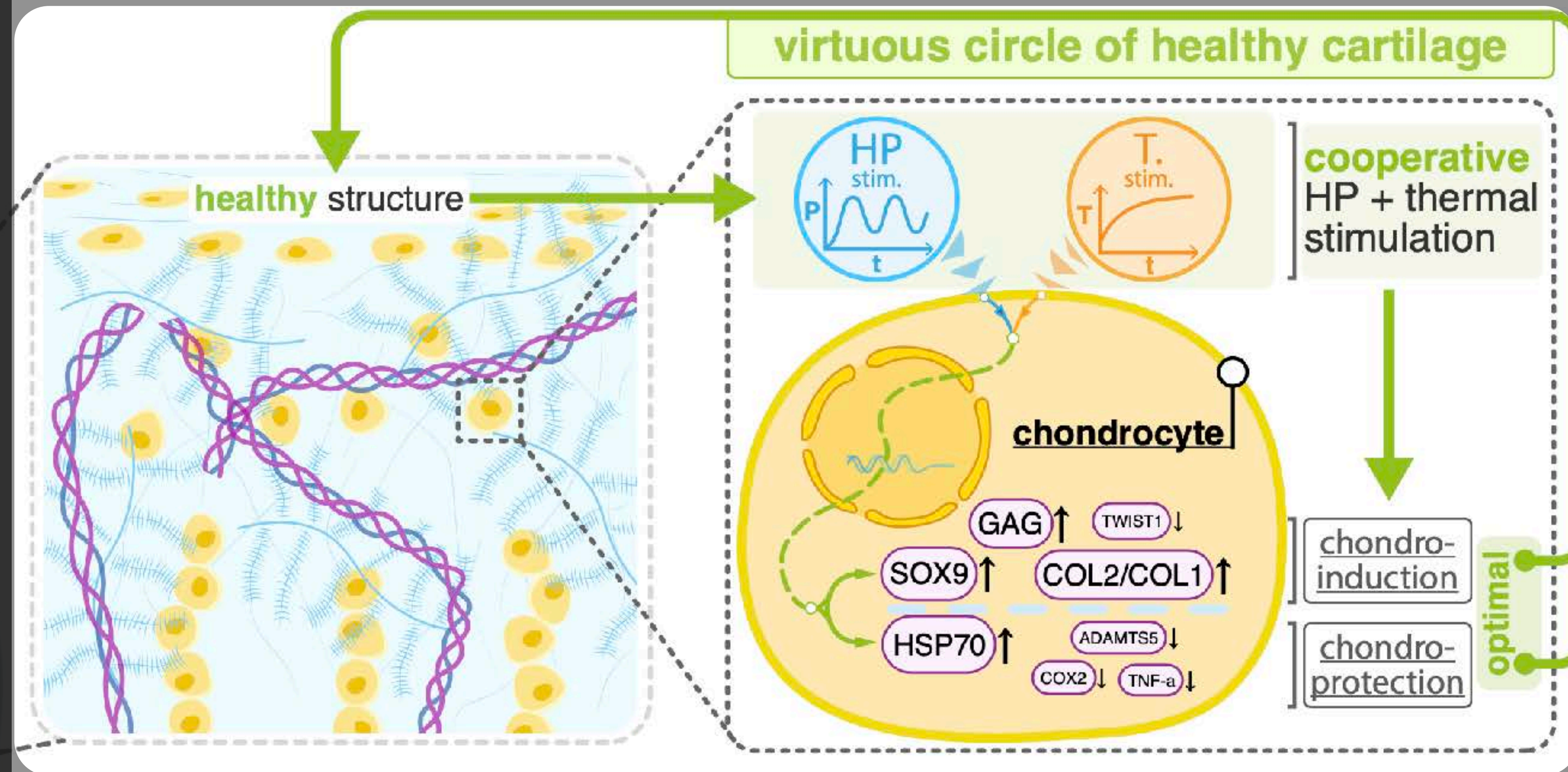


Proposed mechanism of cartilage homeostasis (focusing on HP-T)

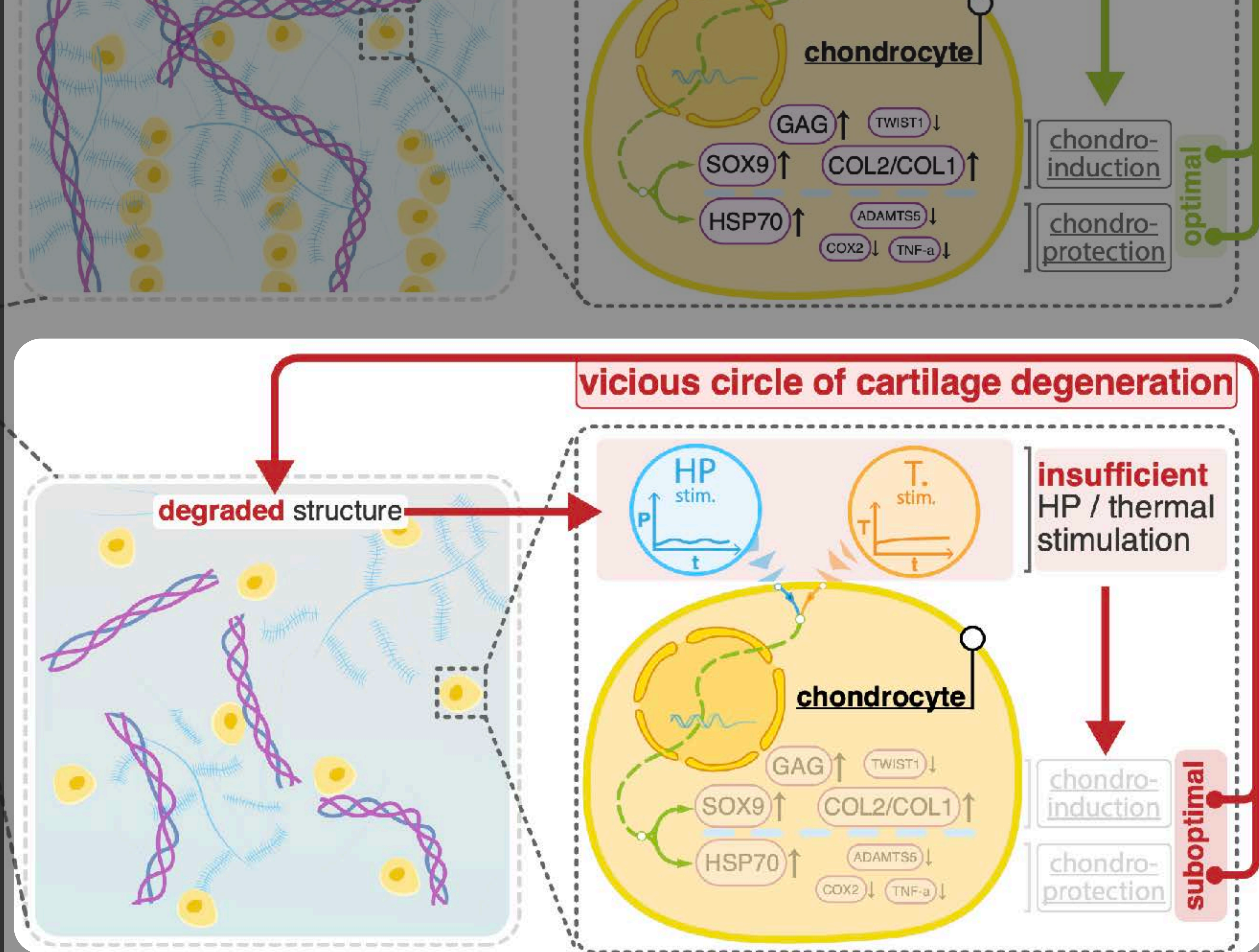


healthy cartilage degraded cartilage

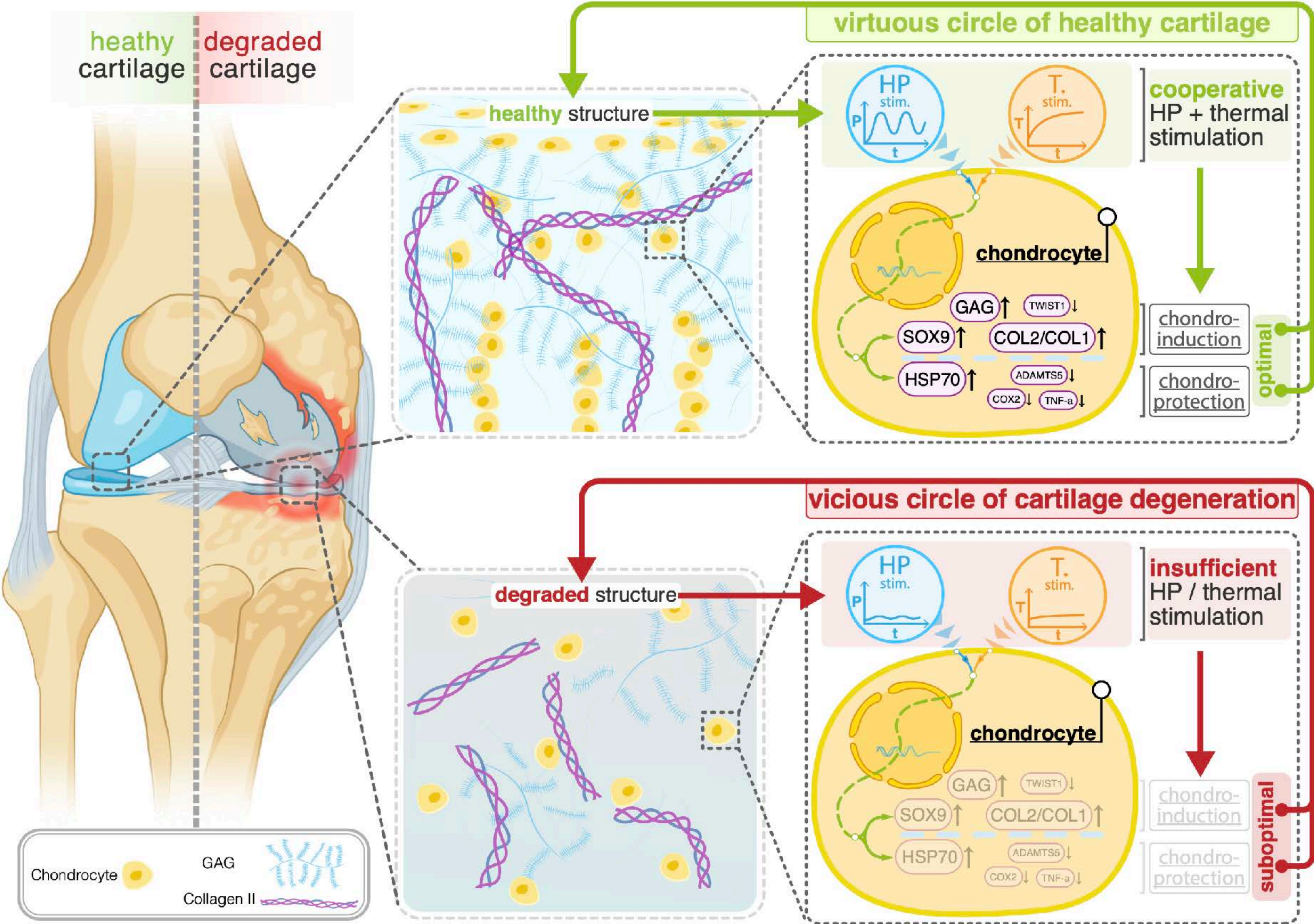
Proposed mechanism of cartilage homeostasis (focusing on HP-T)



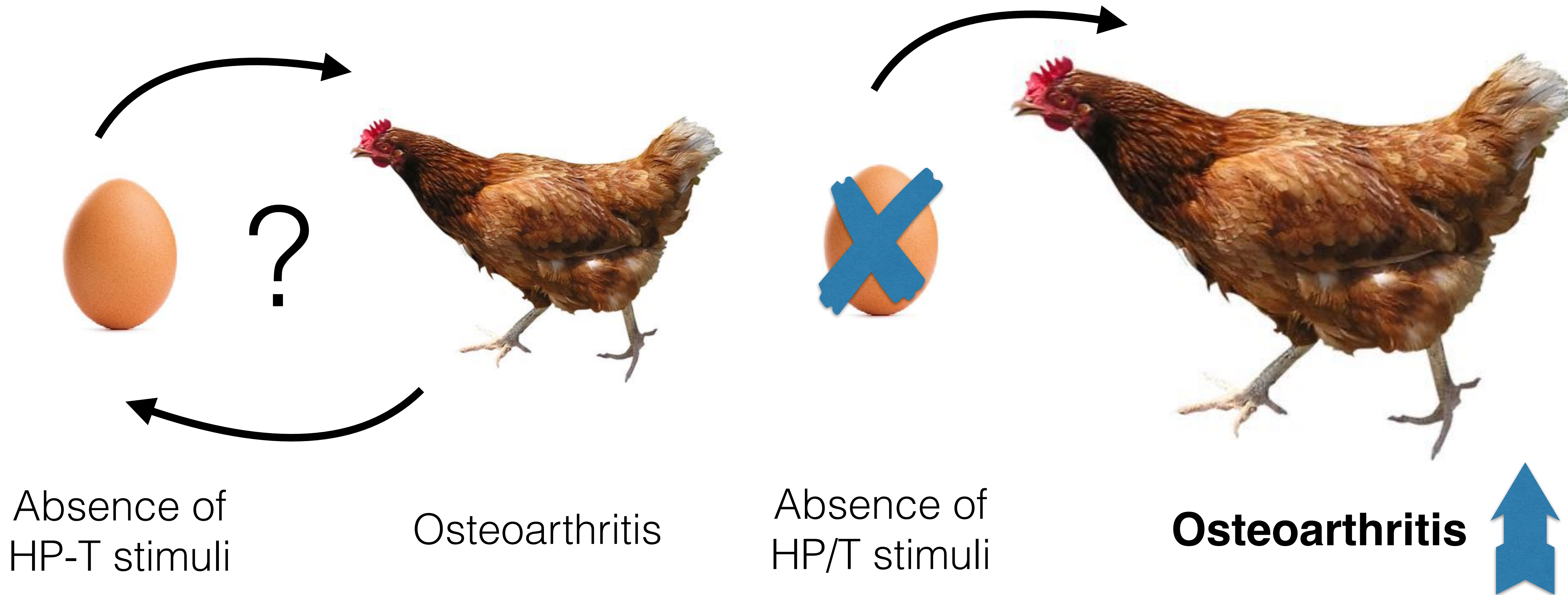
Proposed mechanism of
cartilage homeostasis
(focusing on HP-T)



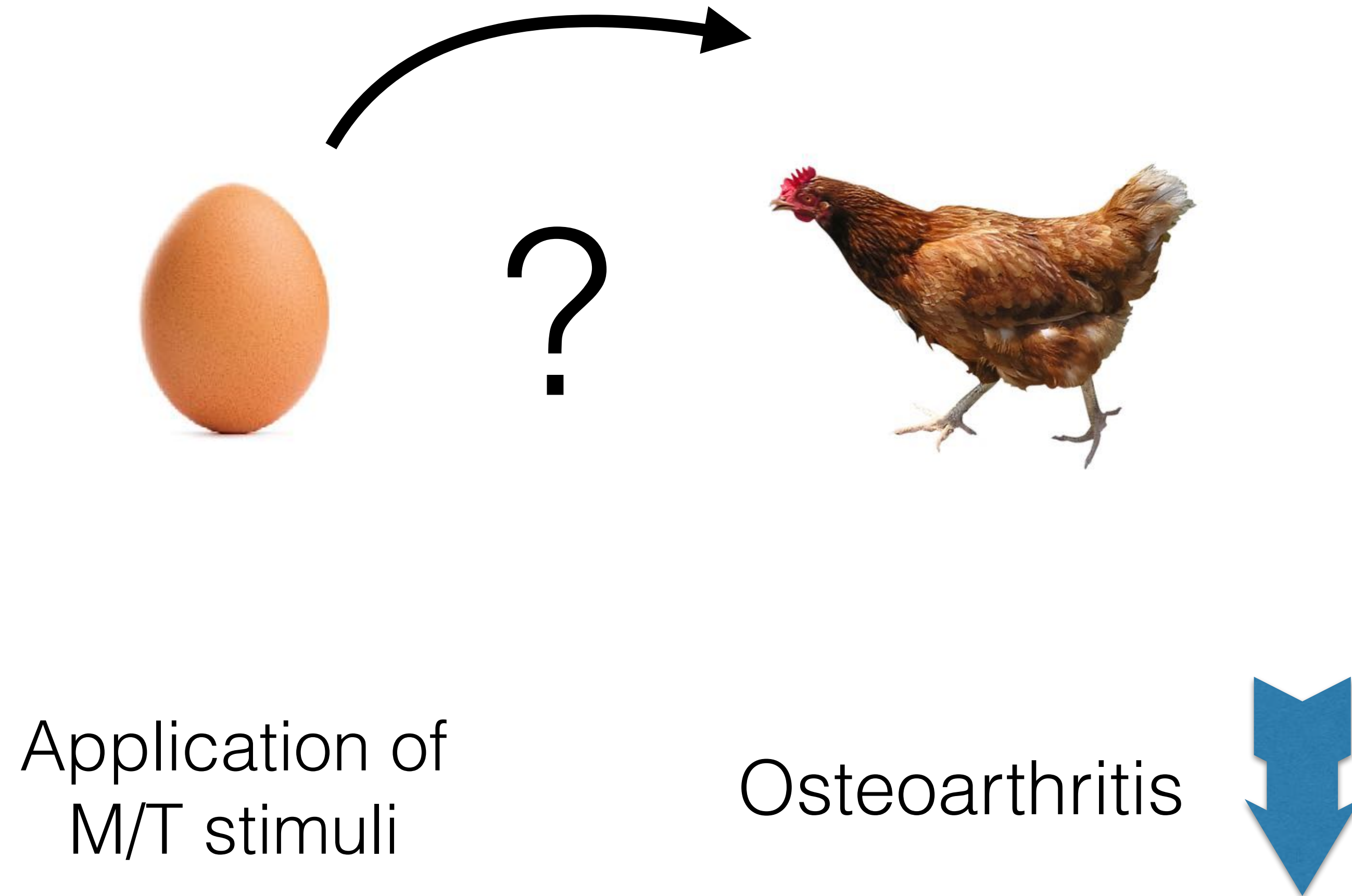
Proposed mechanism of cartilage homeostasis (focusing on HP-T)



Egg and chicken problem



Egg and chicken problem



Effect of heat and exercise to relieve OA pain

Original Article

Egyptian Journal of Health Care, 2020 EJHC Vol. 11. No.3

Effect of physical Exercise and Heat Application on Pain and Morning Stiffness in Osteoarthritis Patients

Shereen Abd El Moniem Ahmed ⁽¹⁾, Wafaa Ismaiel Shereif ⁽²⁾, Shereen Reda Hassan ⁽³⁾, Nagwa Mohamed Helmy ⁽⁴⁾

- (1) Assist. Prof of Medical-Surgical Nursing, Faculty of Nursing, Suez Canal University
(2) Professor of Medical-Surgical Nursing, Faculty of Nursing, Mansoura University
(3) BScN, Zagazig University, Master student, Faculty of Nursing, Suez Canal University
(4) Lecturer of Medical-Surgical Nursing, Faculty of Nursing, Suez Canal University



Archives of Gerontology and Geriatrics
Volume 57, Issue 3, November–December 2013, Pages 352-359



Effectiveness of exercise with or without thermal therapy for community-dwelling elderly Japanese women with non-specific knee pain: A randomized controlled trial

Hunkyung Kim ^a, Takao Suzuki ^b, Kyoko Saito ^a, Miji Kim ^a, Narumi Kojima ^a, Tatsuro Ishizaki ^a, Yukari Yamashiro ^a, Erika Hosoi ^a, Hideyo Yoshida ^a

INTERNATIONAL JOURNAL
of NURSING PRACTICE

ORIGINAL RESEARCH PAPER | [Full Access](#)

Application of heat and a home exercise program for pain and function levels in patients with knee osteoarthritis: A randomized controlled trial

Songul Karadağ RN, PhD, Sultan Taşcı RN, PhD, Nurhan Doğan RN, Hüseyin Demir PhD, MD, Züleyha Kiliç RN

First published: 22 August 2019 | <https://doi.org/10.1111/ijn.12772> | Citations: 6



Clinical Biomechanics
Volume 57, August 2018, Pages 107-113



Effects of supplemental heat therapy in multimodal treated chronic low back pain patients on strength and flexibility

Jürgen Freiwald ^a, Matthias Wilhelm Hoppe ^a, Wilhelm Beermann ^b, Jurek Krajewski ^c, Christian Baumgart ^a



Topics in
**Geriatric
Rehabilitation**

[Articles & Issues](#) | [Collections](#) | [Blog](#) | [For Authors](#) | [Press Releases](#) | [Journal Info](#)

Outline
Images
Download

OFF THE TOPIC

Is Therapeutic Exercise Clinically Effective in Reducing Pain Intensity in Patients With Knee Osteoarthritis? A Systematic Review

Beydağı, Muharrem Gökhan PT; Bazancir, Zilan PT; Bozgeyik, Sibel PT; Ülge, Ozlem PhD, PT

Author Information

Topics in Geriatric Rehabilitation 37(2):p 89-103, April/June 2021. | DOI: 10.1097/TGR.0000000000000309

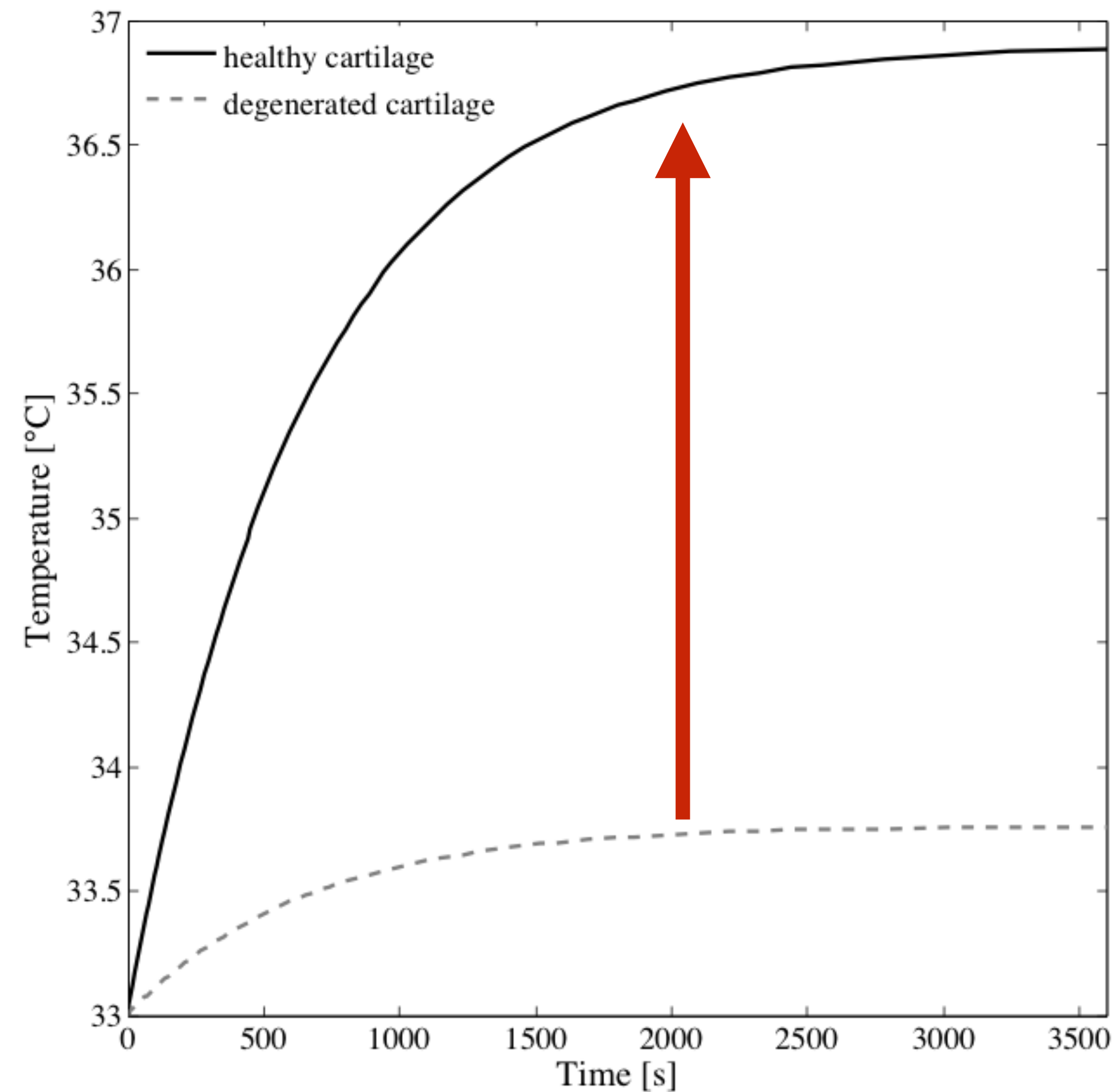
Matrix

Can we use thermomechanical stimulation to compensate for the loss of dissipative cartilage abilities?

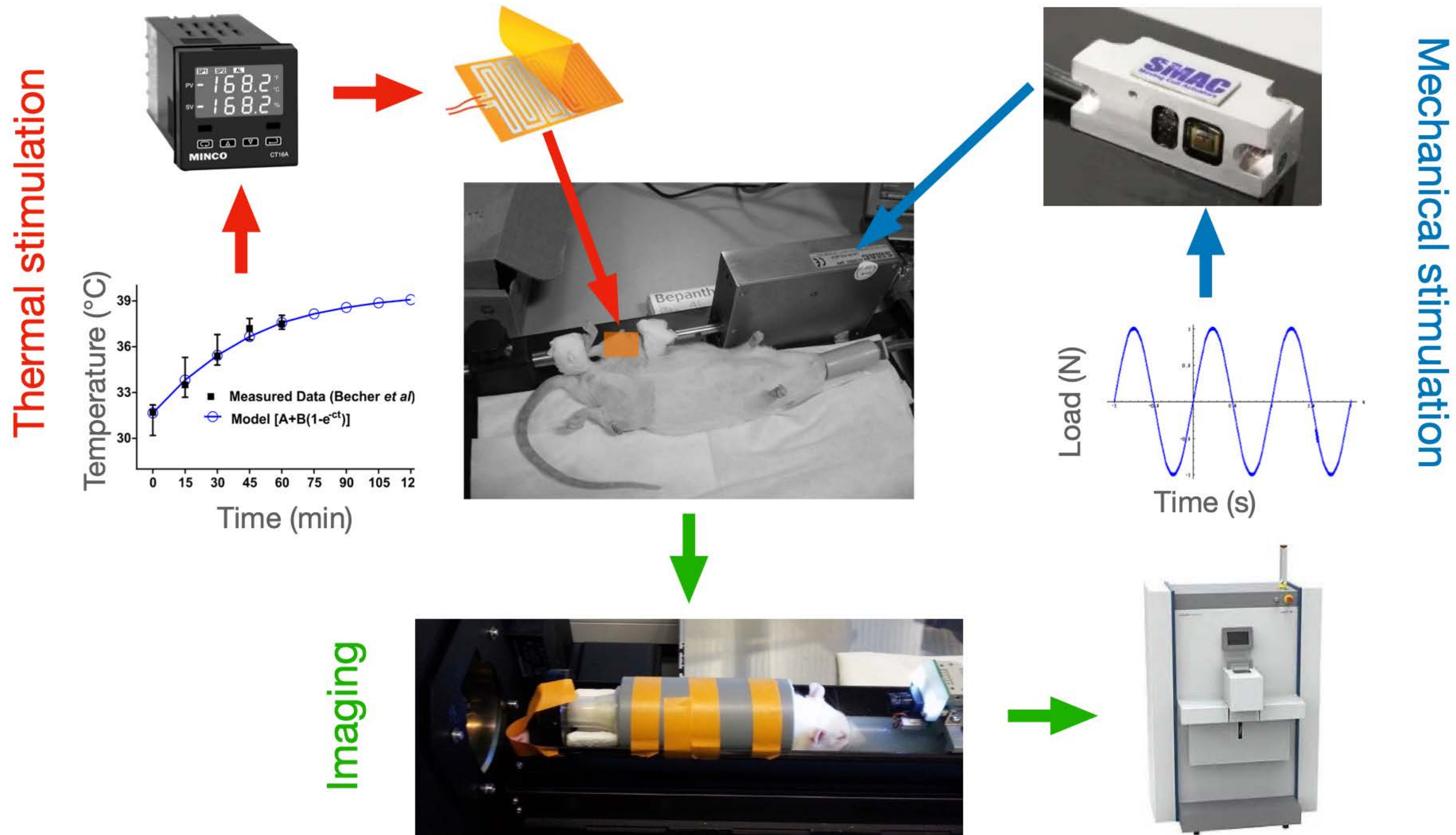


Onsen is undoubtedly bringing some health benefits, but it is not enough:
It is a thermal but not a thermomechanical stimulus

Can we use thermomechanical stimulation to compensate for the loss of dissipative cartilage abilities?



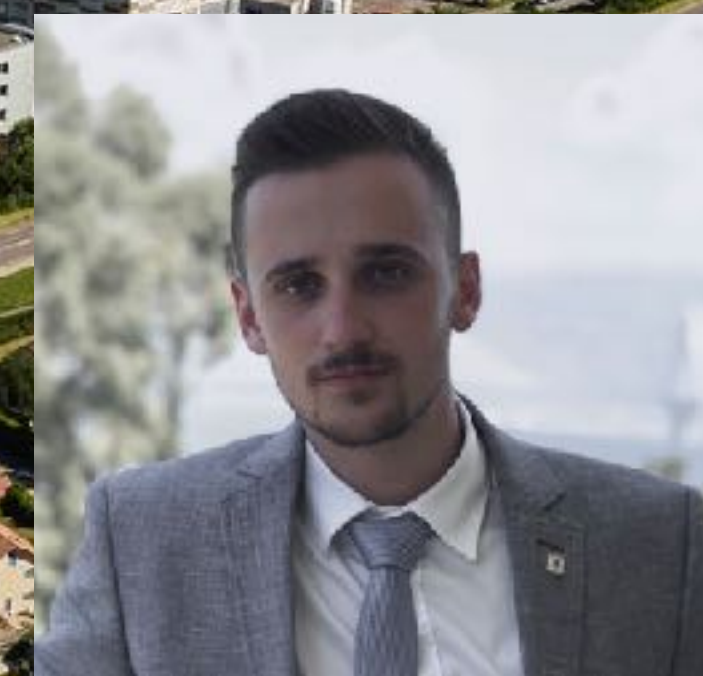
In other words, could thermomechanical stimulations revert osteoarthritis?



Thermomechanobiology: the next frontier for treating osteoarthritis



Yanheng Guo



Theofanis Stampoultzis

EPFL