ACUPUNCTURE: modeling & simulating

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application

- Western anesthesia: coma-like state (irrelevant, used for the convenience of surgeons).
- Acupuncture: appropriate + quick postoperative recovery + low cost health system (to be promoted)
 Brain: a wonderful chemical processor (natural analgesia &anesthesia)

e mode of operation

- signaling via nervous impulses and
- signaling via endocrine messengers conveyed by blood flow They must cross BBB or more permeable capillary networks in neuroendocrine nuclei.

Operating modes

- Long-term training to handle acupoints and become an expert
- 4 main techniques that can be combined
 - development of a local mechanical stress field by needle motions (lifting-thrusting cycle or rotation) at acupoints (mechanotransduction);
 - development of a local temperature field by directly applying a heating moxa (mugwort herb) stick on the skin or indirectly by applying this stick ot the acupuncture needle (moxibustion) at acupoints;
 - development of a local electrical field by applying a small electric current between a pair of acupuncture needles (electroacupuncture, or percutaneous electrical nerve stimulation [PENS]) at acupoints.
 - stimulation of photosensitive GPCRs by laser light at acupoints in the absence of physical effects.

- MASTOCYTES (subcutanous tissue—hypodermis);
 - contains granules storing chemical mediators
 - release granule content within minutes for intra-, auto-, juxta-, para-, and endocrine signaling.
- adjoining NEURAL TERMINALS;
- CAPILLARIES (high density);
- high ionic concentrations (K⁺, Ca⁺⁺, Fe⁺⁺, Mn⁺⁺, Zn⁺⁺, PO₄³⁻).

recruitment to acupoints — chemotaxis

self-sustained process that enables continuous secretion of messengers by arrivals of new mastocyte pools from nearby capillaries and regional mastocyte populations

- transmigration of circulating mastocytes (across blood vessel walls, i.e., exit from blood)
- migration of loaded (granulated) mastocytes across a region of low-amplitude mechanical stress [threshold l])
- migration across a region of triggering mechanical stress and unloading (degranulation) [close to needle: 0—l]

Nerve terminals

- immediate triggering (O[1 s-1mn]) of fast, short-lived action potentials, but sustained action due to cell recruitment;
- hyperemia in a given local brain region (attractor for endocrine messengers);
- neurotransmission using endocannabinoids, antalgics, etc.
- Capillaries increase in permeability (enhanced transport)
 - blood and lymph convection of endocrine messengers to the brain
 - delayed, slower, but sustained (because of cell recruitment)

Heart increase in blood flow rate

Brain wanted afferent signaling

- mechanosensitive Ca²⁺ channel
- thermosensitive Ca²⁺ channel
- voltage-gated Ca²⁺ channel
- Ga²⁺ channel coupled with photosensitive GPCRs

SECONDARY PLAYERS

Agent	Effects
CGRP	Vasodilation,
	positive chronotropy, inotropy, and lusitropy,
	mastocyte degranulation
Heparin	Blood clot prevention
Histamine	Vasodilation (directly and via NO),
	nerve stimulation
Leukotrienes	Vasodilation, vascular permeability elevation
IL, NGF, TNF	Chemotaxis
Prostaglandin-D2	Nerve stimulation
Prostaglandin-E2	Vasodilation,
	inhibition of mediator release
Serotonin	Vasoconstriction followed by
	NO-mediated vasodilation
Thromboxane-A2	Vasoconstriction, platelet aggregation
Tryptase, chymase	Matrix degradation for enhanced cell migration

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SUMMARY of EVENTS

- generation of a local stress field
- mechanotransduction (Ca²⁺ entry, granule exocytosis, substance release)
- triggering of action potential (early, quick response)
- chemotaxis (from regional pools and blood)
- degranulation of newly arrived mastocytes at acupoints (autosustained process)
- local elevation of vascular permeability for enhanced endocrine signaling and improved cardiac output
- vasodilation with increased blood flow (cardiac effect)
- delayed, permanent endocrine signaling to CNS (preferential distribution in hyperemic region)

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- Relatively high density of resting mastocytes at acupuncts;
- 2 mastocyte states according to localization w.r.t. acupoint: non-degranulated and degranulated;
- Quasi-instantaneous release of chemical mediators upon stimulation (mechanotransduction & calcium influx);
- release of chemoattractants, nerve messengers, cardiovascular stimulants, and endocrine messengers;
- delayed regeneration of granules content,
- negligible convection (Stokes flow) in the matrix

For $x \in \Omega$ bounded and $t \in \mathbb{R}^+$:

- $n_g(t, x)$: density of granulated mastocytes
- $n_d(t, x)$: density of degranulated mastocytes
- c(t, x): concentration of chemoattractant
- $s_n(t, x)$: concentration of nerve stimulant
- $s_e(t, x)$: concentration of endocrine stimulant

equation related to granulated mastocytes equation related to the pool of degranulated mastocytes equation related to chemoattractant equation related to nervous messenger equation related to endocrine messenger



mastocyte/chemoattractant/nervous messenger/endocrine mediator

$$\partial_t n_g - \mathcal{D}_m \nabla^2 n_g + \nabla \cdot (\mathsf{S} n_g \nabla c) = -\mathsf{A} \Phi n_g + \mathsf{R} n_d; \quad (1)$$

$$\partial_t n_d - \mathcal{D}_m \nabla^2 n_d = A \Phi n_g - R n_d;$$
 (2)

$$\partial_t c - \mathcal{D}_c \nabla^2 c = \kappa_c A \Phi n_g - D_c c;$$
 (3)

$$\partial_t s_n - \mathcal{D}_n \nabla^2 s_n = \kappa_n A \Phi n_g - D_n s_n;$$
 (4)

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$$\partial_t s_e - \mathcal{D}_e \nabla^2 s_e = \kappa_e A \Phi n_g - D_e s_e; \quad (5)$$

$$t > 0; \quad \mathbf{v} \in \Omega$$

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$$\Phi(x)$$
: magnitude of mechanical stress $0 \le \Phi(x) \le 1$ ($0 \le x \le \ell$);

- A: activation rate [T⁻¹];
- R: regeneration rate of degranulated masotocytes [T⁻¹];
- S: mastocyte sensitivity to chemoattractant ([L⁴mol⁻¹T⁻¹]);
- κ_{c,e,n}: release quantity coefficient [mol].

equations physically homogeneous

PLAY SITE



acupoint: high-amplitude, low-dispersion distribution of mastocytes (Gaussian distribution toward Dirac function)

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STORY



different axis magnitude

blow up (efficiency) vs. mild response

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Confucius rule-like recipies for healthy life

to reach your 100th birthday

- Eat chocolate regularly to avoid depression;
- Eat brocoli as often as possible (according to Michael);
- Eat raw fish to avoid degenerescence of your tate sensors;
- Eat Roquefort cheese and French wine to struggle against CVD;
- Make your daily soya milk;
- Walk every day at least 1 h with your nice wife Daphne;
- Practice Yangmingshan at least 1/wk and reach the top, whatever the weather;
- Travel to maintain culture investigation;
- Write book(s) to excite your neurons;
- Have good sleep;
- If your are unhappy with political power, depose.

THANK YOU FOR YOUR ATTENTION

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