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Bone Remodeling

We will use COMSOL to implement a simple bone remodeling simulation, more precisely a simplified version of the model described by Mullender & Huiskes, 1995. The evolution of "relative bone density" m shall be governed by

$$\dot{m}(\boldsymbol{x},t) = \tau \cdot (S(\boldsymbol{x},t) - k)$$

with the strain energy density (SED) S, a reference SED k and a remodeling rate constant τ. In this simplified model, the remodeling stimulus is thus simply the deviation of the SED at the current location from a reference value, *but not* the weighted influence of surrounding "osteocytes".

Mechanical loads, boundary conditions and other parameter values should generally correspond to those described in the paper. Only for the parameter k we recommend a slightly different value of $k = 0.05$ MPa.

Tasks

1. Implement the model using COMSOL (2D, time-dependent).
2. Compare your results to those presented by Mullender & Huiskes 1995.
3. Investigate the influence of the parameters.

Suggestions

- Your model should consist of two "physics" components: "Solid Mechanics" to compute the SED and a "Coefficient Form PDE" to describe the evolution of m.
- Initial conditions: Instead of a homogenous density distribution, we recommend using a simple initial structure, e.g. a "trabecular grid", instead.
- It is critically important to ensure $0 < m \leq 1$. Hint: The `if`-operator may proof useful.
- For a more stable solution, choose "discontinuous Lagrange" with a "constant" Ansatz for the discretization of m (meaning that m is considered to be piecewise-constant).