Biot ∩ Bones ∩ Rocks

Geophysical vs. Biomechanics
Infinite domains vs. finite domains
Unknown microstructure vs. known microstructure
Transient loading vs. periodic loading
Time scale of millennia vs. hours
The earth is a living body. Its soul is its ability to grow. This soul, which also provides the earth with its bodily warmth, is located in the inner fires of the earth, which emerge at several places as baths, sulfur mines or volcanoes. Its flesh is the soil, its bones are the strata of rock, its cartilage is the tufa, its blood is the underground streams, the reservoir of blood around its heart is the ocean. the systole and diastole of the blood in the arteries and veins appear on the earth as the rising and sinking of the oceans.
Application to articular cartilage

\[ \text{The Skempton Factor } B; \ \delta p = -B \delta \sigma_{kk}/3 \]

\begin{align*}
B \rightarrow 1 & \quad \text{Soft tissues} \\
B < 1 & \quad \text{Hard tissues}
\end{align*}

Water saturated soils \quad \text{Marble and granite}

(undrained)
THE LACUNAR POROSITY

THE CANALICULAR

THE LACUNAR

THE CANALICULAR POROSITY
<table>
<thead>
<tr>
<th>Property</th>
<th>Lacunar-Canalicular Porosity</th>
<th>Marble</th>
<th>Granites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear modulus</td>
<td>G(N m⁻²) x 10⁻¹⁰</td>
<td>0.5</td>
<td>2.4</td>
</tr>
<tr>
<td>Poisson Ratio</td>
<td>ν</td>
<td>0.32</td>
<td>0.25</td>
</tr>
<tr>
<td>Poisson Ratio</td>
<td>ν_u</td>
<td>0.33</td>
<td>0.27</td>
</tr>
<tr>
<td>Bulk modulus</td>
<td>K(N m⁻²) x 10⁻¹⁰</td>
<td>1.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Bulk modulus</td>
<td>K₀(N m⁻²) x 10⁻¹⁰</td>
<td>1.3</td>
<td>4.4</td>
</tr>
<tr>
<td>Skempton Co.</td>
<td>B</td>
<td>0.40</td>
<td>0.51</td>
</tr>
<tr>
<td>Bulk modulus</td>
<td>Kₛ(N m⁻²) x 10⁻¹⁰</td>
<td>1.4</td>
<td>5.0</td>
</tr>
<tr>
<td>Eff. Stress Co.</td>
<td>α</td>
<td>0.14</td>
<td>0.19</td>
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<tr>
<td>Porosity</td>
<td>ν₀</td>
<td>0.05</td>
<td>0.02</td>
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<tr>
<td>Pressure diffusion Co</td>
<td>c(m² s⁻¹) x 10⁶</td>
<td>0.51</td>
<td>13</td>
</tr>
<tr>
<td>Permeability</td>
<td>k(md) x 10⁴</td>
<td>15</td>
<td>1.0</td>
</tr>
</tbody>
</table>
**Fluid pressures in bone**

\( p_B \) = Blood pressure, about 60 mmHg or 8kPa or 1.16 psi.

\( p_C \) = Collapse pressure for the blood vessels, \( p_C = p_B + \) a little bit

\( p_{VP} \) = Bone fluid pressure in the vascular porosity

\( p_{LC} \) = Bone fluid pressure in the lacunar canalicular porosity

If \( p_{VP} \geq p_C \) for a long period of time, cell death will occur.

If \( p_{LC} \geq p_C \), no problem.
Illustration of an RVE for a poroelastic medium.
A 1941 paper of M. A. Biot that clearly describes a representative volume element (RVE) “Consider a small cubic element of soil, its sides being parallel with the coordinate axes. This element is taken to be large enough compared to the size of the pores so that it may be treated as homogeneous, and at the same time small enough, compared to the scale of the macroscopic phenomena in which we are interested, so that it may be considered as infinitesimal in the mathematical treatment.”

“To this end, the concept of a representative volume element (RVE) is introduced; Hill (1963), Hashin (1964, 1983), Kriner (1977), Willis (1981), and Nemat-Nasser (1986).”