ELEC ENG 3BA3:
Structure of Biological Materials

Notes for Lecture #15
Wednesday, October 31, 2012
5.3 Artificial organs

Some of the main chemical producing or processing organs of the body that are candidates for artificial replacements include the:

- kidneys,
- liver,
- pancreas,
- glands, and
- organs of the GI tract.
Classes of artificial organs:

Include:

- *non-biological* chemical processing plants
- *bioartificial organs* using modified xenografts or allografts
- *tissue-engineered* organs
Classes of artificial organs (cont.):
Housing of artificial organs:

- The majority of totally-artificial and bioartificial organs are too large to be implanted in the body ⇒ extracorporeal housing

- *Intracorporeal* housing is only possible with smaller totally-artificial & bioartificial organs and tissue-engineering organs
Examples of totally-artificial organs:

- Hemodialysis (artificial kidney)
- Artificial pancreas
- Liver dialysis
Filtration and dialysis by normal kidneys:

Fig. 4.11 Qualitative material balances on the body, with details of the kidney and how its nephrons function. Two very different membrane processes are involved, with their coupled processing of the blood responsible for fine-tuning of the body’s water balance and salt balance and for all elimination of metabolic byproducts.
Artificial hemodialysis:
Artificial hemodialysis (cont.):

Fig. 4.12 Function of the AK. It operates primarily by dialysis, though a small amount of ultrafiltration may occur (not shown). Salts may be exchanged across the membrane in either direction, depending on composition of the dialysate. A typical dialysate composition (mmol L$^{-1}$) for treating a patient in renal failure (plasma levels in parentheses) would be: 132 (128) Na$^+$, 1 (6) K$^+$, 2.0 (1.6) Ca$^{2+}$, 1.6 (0.5) Mg$^{2+}$, 102 (92) Cl$^-$, 36 (12) HCO$_3^-$, 0 (1.2) PO$_4^{3-}$, 0 (0.8) SO$_4^{2-}$, the corresponding normal levels are approximately 132, 4, 2.0, 1.5, 102, 26, 0.7, and 0.5, respectively.

Fig. 4.13 Schematic representation of a portable, disposable dialyser unit operating with hollow-fiber technology. The drawing, with approximate dimensions, grossly exaggerates the spacing between fibers and fiber size in order to show the dialysate flow path; actually, the 10,000 fibers are extremely close to each other.
Implantable artificial pancreas:

(Medtronic MiniMed 2007)
Liver dialysis:
Molecular Adsorbent Recirculation (MARS)
Liver dialysis (cont.):
Examples of bioartificial organs:

- Bioartificial liver
- Bioartificial parathyroid gland
Bioartificial liver:
Bioartificial liver using human hepatocytes:

(Rahman et al., Artif. Organs 2004)
Bioartificial liver using porcine hepatocytes:

(Lorenti et al., Artif. Organs 2003)
Microencapsulation of parathyroid tissue:

1.5% alginate solution mixed with parathyroid gland

1. Alginate solution mixed with parathyroid gland
2. Polymer solution
3. 400-W high pressure mercury lamp
4. s.alginate-MPEG
5. Sodium citrate

(Lee et al., Artif. Organs 2004)
Requirements for tissue engineering organs:

1. Scaffold (on which to grow the cells)
2. Differentiable cells
3. Correct chemical environment and chemical signalling
Scaffolding (additive methods):

PRINTING ORGANS

Organs could be built up layer by layer by printing clumps of cells onto a gel that turns solid when warmed. Once the cells have fused the gel can be removed simply by cooling it.
Scaffolding (*subtractive methods*):

![Diagram showing the processes of solution formation, cooling, phase separation, sublimation, and polymer foam formation.](image)

*Figure 6.13* Controlled rate freezing and drying. Microstructure of scaffolds formed using a mixture of chitosan and gelatin.
Examples of tissue-engineered organs:

– Liver

– Stomach

– Colon

– Bladder
Tissue-engineered liver:

A  Vascularized Implant

B  Micro-encapsulated Implant

(Chan et al., Liver Transpl. 2004)
Tissue-engineered stomach and colon:

(Maemura et al., ASAIO J. 2004)  
(Grikscheit et al., Surgery 2002)