生物材料學 BIOMATERIALS

Biocompatibility: Definition and Issues

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Purpose of the Class

To develop in the students a familiarity with the uses of materials in medicine and with the rational basis for these applications.

Introduction

1. Introduction

- This issue rises from a recognition of the profound differences between *living tissues* and *nonliving materials*

  - a wide range of interactive behavior between tissues and materials → beneficial or detrimental effects

1. Introduction

e.g., foods & beverage - nutritious or nonnutritious
- toxic or nontoxic

→ relative to use or abuse rather than to an absolute scale

e.g., alcohol - although a central nervous system depressor, has a positive virtue as a disinhibiting stimulant and social drug in small doses

→ In large doses it is toxic and, in still larger doses, lethal

1. Introduction

- *Biomaterials*

  - materials of natural or manmade origin that are used to direct, supplement, or replace the functions of living tissues

  - when these materials evoke a *minimal* biological response

    - *biocompatible*

      * The term ‘biocompatible’ as used here is inappropriate and defective of content

      * *Compatibility* – strictly the quality of harmonious interaction

        → the label ‘biocompatible’ suggests that the material display universally ‘good’ or harmonious behavior in contact with tissue and body fluids

1. Introduction

- Effects of biological processes on materials are rarely included in the traditional ideas of biocompatibility (unless the results of material changes)
  - *e.g.,* biodegradation
    - elicit a change in biological response
- At present, the most common approach to establishing the biocompatibility of a material is to establish the *absence* of deleterious effects due to its use in biological applications

→ Once such tests are completed, the material is regarded as *qualified*

1. Introduction

- The real issues in the use of biomaterials in medical and surgical devices are *not absolute*
- The real issue of biocompatibility is not whether there are adverse reactions to a biomaterial, but whether that material performs satisfactorily (*i.e.,* in the intended fashion) in the application under consideration

  → among the factors considered must be the *interaction* of the material with the biological processes in its intended site of operation (on a *relative* basis)

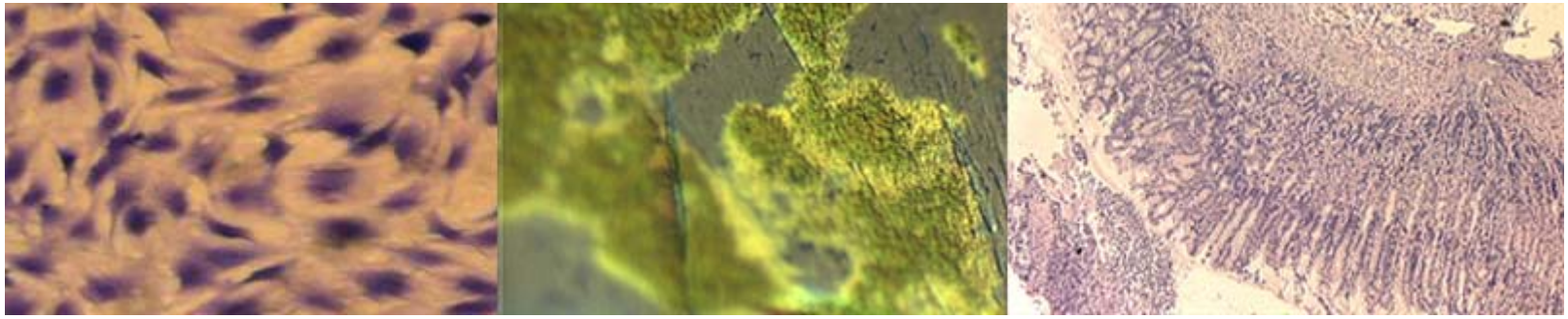
Biological performance

2. Biological performance

- *Biological performance*

  - will be here adopted as a descriptor of material to replace the present idea of biocompatibility

  - the *interaction between materials and living systems*



2. Biological performance

- Two aspects of this performance:
  - *Host response*
    - The local and systemic response (other than the intended therapeutic response) of living systems to the material
  - *Material response*
    - The response of the material to living systems

    → the need for a system of grading based upon the results of tests
    (i.e., on a *relative*, rather than an absolute, basis)

2. Biological performance

- Two other closely related terms:
  1. *Reference (or control) materials*
     – A material that, by *standard test*, has been determined to elicit a reproducible, quantifiable host or material response

     → no implication of *'good'* or *'bad'*

     (1) negative reference material

     – a material with *minimal* host response

     (2) positive reference material

     – a material with an *extreme* host response

2. Biological performance

2. *Level of host (or material) response*

– The nature of the host (or material) response in a standard test with respect to the response obtained with a *reference material*

* *Standard test* – any well-defined, repeatable test (for biological performance)

2. Biological performance

- It is suggested that the use of the term ‘biocompatibility’ is retained for *historical* reasons, but with a *narrow* and careful redefinition:

- *Biocompatible (-ity)*

  – *Biological performance* in a *specific* application that is judged *suitable* to that situation

2. Biological performance

- When host and material response are known and the particular device application is examined

  → a final value judgment can then be made

  → leads to the acceptance or rejection of the material

  ⇨ Such a selection and a resulting record of adequate performance does *not 'qualify'* a material

  → Rather, it increases the confidence in the use of the material and points to *possible* successful use in similar applications

Consensus definition

3. Consensus definition

- Thirteen terms gained consensus definitions in the European Society for Biomaterials in 1986

  →Those that are relevant to this discussion are:

  1) *Biomaterial*:

     A nonviable material used in a medical device, intended to interact with biological systems

  2) *Host response*:

     The reaction of a living system to the presence of a material

  3) *Biocompatibility*:

     The ability of a material to perform with an appropriate host response in a specific situation

- These definitions preserve the idea of ***interaction***, of *relative* rather than absolute attributes.

Discussion

4. Discussion

- *Qualification*
  - the careful development of standard tests
  - the characterization of *reproducible response relative to reference materials*
- Absolute qualification
  - is not possible for an artificial or processed material in biological applications

→ It is necessary to establish minimum requirements for performance at various stages of materials development

4. Discussion

- ***Biocompatible*** ⇨ **Physiologically tolerable**

  → somewhat overlook the benign responses elicited by many materials in living systems

- However, living systems differ most from machines in respect to the constant flux and change of their components → *i.e.,* in their ***physiology***

4. Discussion

- Biological performance

  - particularly *host response*

  - ought not be defined in terms of tissue structure and pathology but primarily in terms of *physiology* (*e.g.*, knowledge of the participation of the material in the physiology of the host)

  - Deviations from usual physiological conditions

    → may lead to *changes* in the structure and function of living tissues

4. Discussion

- Biomaterials were classified based on physiological considerations (Osborn, 1979):

  Biotolerant – negative (but tolerant) local host response

  Bioinert – absence of local host response

  Bioactive – positive (desired) local host response

4. Discussion

- Examining the *historical* development of biomaterials, it is possible to define *four phases* or *types* of biomaterials, based upon changing concepts of *host response*:

  Phase 1. Inert (biomaterials)

  – implantable materials which elicit *little* or *no* host response

  Phase 2. Interactive (biomaterials)

  – implantable materials which (∴ host response is inevitable) are designed to elicit *specific*, *beneficial* responses, such as ingrowth, adhesion, etc.

4. Discussion

Phase 3. Viable (biomaterials)

– implantable materials (possibly *incorporating live cells* at implantation) which are treated by the host as normal tissue matrices and are actively *resorbed* and/or *remodeled*

Phase 4. Replant (biomaterials)

– implantable materials consisting of *native tissue*, cultured in vitro from *cells* obtained previously from specific implant patient

4. Discussion

- Searches for Phase 1 materials → pointless
- Many biomaterials in present clinical use & ones in development → Phase 2 materials
- Preliminary research reports reveal great interest and promise → Phase 3 materials
- Advances in control and manipulation of the *genetic code* in mammals suggest that no intellectual barrier exists to prevent the broad future realization of Phase 4 materials at both the tissue and organ level

4. Discussion

- In fact, a Phase 4 material
  -- implantable, live tissue with the identical genetic code and immunological determinants of recipient patient
  -- represents the *ultimate fulfillment* of the original search for *biocompatibility*
  → implantable materials demonstrating *harmonious interaction*
- The limiting factor for artificial devices and implants continues to be biological performance
- Better understanding of biological performance and the factors affecting it will lead to a variety of useful new materials options
  → lead to substantial expansion of the role that artificial devices can play in the prevention and treatment of human disability and disease

4. Discussion

- When the technology for preparation of Phase 4 materials is readily and widely available

  → Artificial devices will be called upon to serve only as *'bridge'* to *replantation*

  → Biomaterials will emerge in its rightful place as one of the healing arts

Reference

- 自行編纂

Summary

- Biomaterials
- Biocompatibility
- Biological Environment
- Swelling and Leaching
- Interfacial-Dependent Phenomena in Biomaterials
- The Structure of Solids
- Characterization of Materials