PREFACE

EDITORIAL FOR BIOINTER*PHASES* IN FOCUS: RESEARCH ON BIOINTERFACES WITH NEUTRONS AND SYNCHROTRON RADIATION

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All materials used by Nature are, in essence, nanostructured and contain multiple interfaces and interphases, since they are composed of nano-size building blocks, such as proteins, filaments, membranes or mineral particles. These nanostructures fulfill multiple essential functions in living organisms, from energy conversion, to chemical synthesis and mechanical stabilization. Typically these nanostructures are assembled into larger assemblies, such as tissue, following hierarchical principles. This gives control over the structure and dynamics of biomaterials over many length scales, and is a major concept for designing artificial multifunctional and adaptive materials. Understanding the principles of hierarchical assembly in living organisms and applying them to engineered materials and structures is—and will be in the future—a grand challenge of materials research with several major research directions.

A first direction is the study of relations between function, structure and dynamics in biological materials,[1] such as plants bodies, cells, extracellular matrix, intracellular materials, as well as uncovering the synthesis, adaptation and healing strategies used by Nature to build, maintain and repair these usually very complex materials. This type of materials research will have direct applications in biomedicine and contribute to research in cellular and structural biology. Most importantly, this research also provides major input into biomimetic materials research, which is based on the understanding of how natural materials work.[2] This type of research will lead the development of novel materials such as

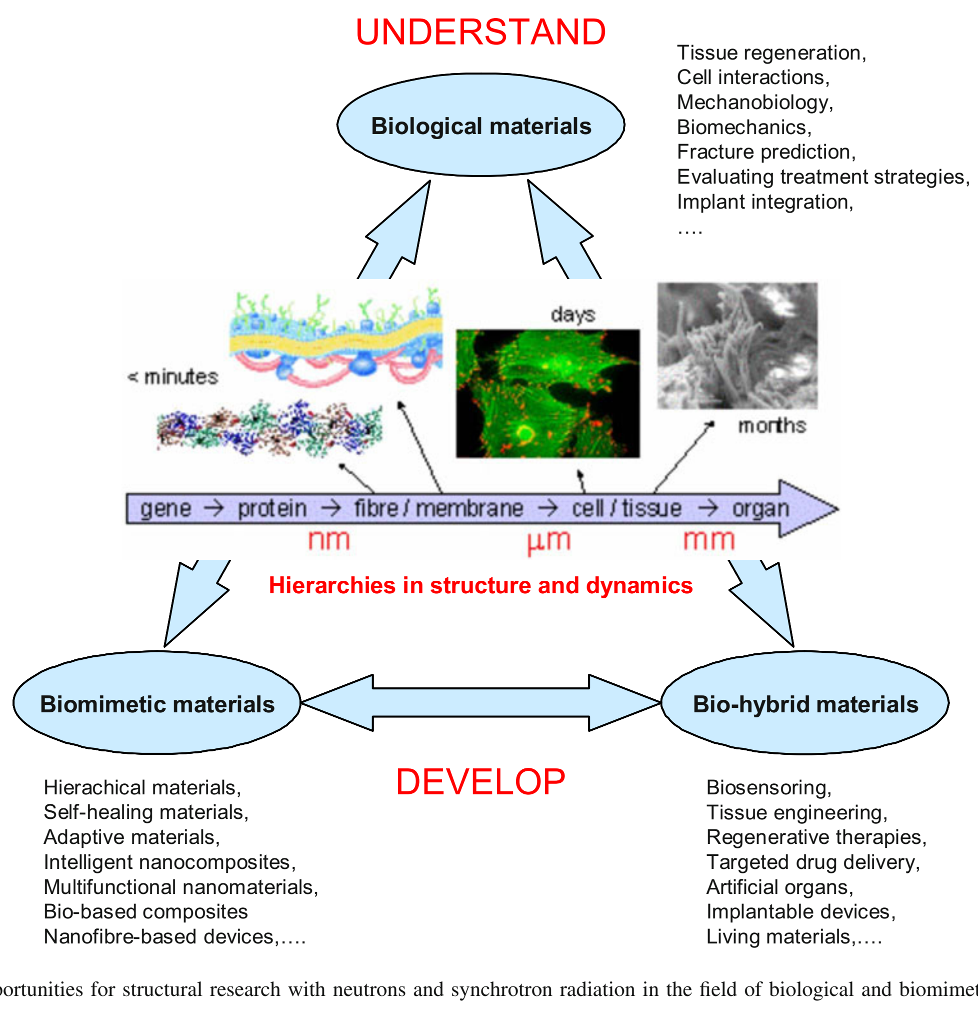

FIG. 1. Opportunities for structural research with neutrons and synchrotron radiation in the field of biological and biomimetic materials

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polymers, ceramics, metals and composites[3–5] or surfaces[6–9] with new properties, e.g., multi-functionality,[10] self-healing capability,[11] adaptivity,[12–17] energy conversion,[18,19] etc. Such materials will find applications in many different fields, from biomedicine (e.g., implants, organ replacements) to transport technology (e.g., aerospace) and information technology (e.g., nanomotors, nanofluidic, molecular electronics, etc.). The ultimate grand challenge is to assemble artificial functional units which reproduce the functionality of cells or even organs (artificial life). This will include scaffolds for tissue engineering,[20,21] *in vivo* implantable permanent biosensors, drug carriers and materials for bioreactors. With the wide-spread efforts to develop new strategies for regenerative medicine,[22,23] there will be the need for a range of new materials which can be integrated as hybrid systems into living systems.

Many types of materials, both soft and hard, can be found in natural tissues. Soft materials include filaments, membranes, gels and tissues built from organic molecules of various sizes and types. Inorganic particles, such as silicates, carbonates, phosphates and various oxides are used as reinforcement of polymeric structures such as in bone and for special purposes, e.g., as magnetic particles for the orientation of birds and insects in the earth's magnetic field. Some of these materials develop their functionally directly as nanostructures. Examples are genetic coding by the DNA or cell motility by actin polymerization and de-polymerization. In many cases, these nano-sized elements are used as building blocks for the assembly of larger functional units, such as muscles or tendons, or the plant cell wall.

In all these research directions, the nanometer scale plays a crucial role, as most of the biological materials are based on nanometer sized building blocks. However, in addition to the nanoscale characteristics, a wide range of dimensions needs to be considered, since most bio-related materials and devices cover multiple length scales to develop their functionality. In terms of structure characterization, this implies that a large range of dimensions and time scales have to be covered. This is a major opportunity for research with neutrons and synchrotron radiation (Fig. 1). Structure-property relations may be determined by "*in-situ*" methods where a specimen is being studied in a time-resolved way during a chemical reaction, a phase transformation or during the response to an external stimulus, such as changes in temperature, magnetic field or mechanical load.

This In Focus section of Biointer*phases* contains reviews and original articles covering a range of applications of neutrons and synchrotron radiation to the study of biological materials, interfaces and surfaces. Readers are encouraged to look up the web pages of the synchrotron and neutron facilities around the world for details on the available instrumentation and research opportunities.

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