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American National Standards Institute

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Nanomedicine Terminology and Standards Workshop

REPORT

12 January 2010

Chemical Heritage Foundation
315 Chestnut Street Philadelphia, PA

Workshop Attendees

ANSI thanks the following individuals who participated in the workshop and contributed to this report.

Dr. Lajos Balogh	Nanomedicine: Nanotechnology, Biology and Medicine, Editor in Chief
Ms. Heather Benko	American National Standards Institute
Dr. Sara Brenner	University of Albany
Mr. Tim Brooke	ASTM International
Mr. Chris Carroll	U.S. Army Center for Health Promotion and Preventative Medicine
Dr. Anne-Marie Chacko	University of Pennsylvania Medical School
Dr. Todd Cecil	US Pharmacopeia
Dr. David Forrest	Foresight Nanotech Institute
Dr. Martin Fritts	National Cancer Institute Nanotechnology Characterization Laboratory
Dr. Pertti Hakkinen	National Library of Medicine
Dr. Elizabeth Hood	University of Pennsylvania Medical School
Dr. Fred Klaessig	Pennsylvania Bionano Systems LLC
Dr. Pei Koay	Chemical Heritage Foundation
Dr. Lance Ladic	Siemens Corporate Research
Ms. Martha Marrapese	Keller and Heckman LLP
Dr. Jody Roberts	Chemical Heritage Foundation
Dr. Michael Schrlau	Drexel University Medical School
Dr. Brian W. Smith	Solixia
Dr. Clayton Teague	National Nanotechnology Coordination Office
Dr. Dennis Thomas	Washington University in St. Louis
Dr. Fraser Wright	Children's Hospital of Philadelphia
Dr. Blaine Zern	University of Pennsylvania Medical School

We thank these Attendees for participating in their individual capacities and thank them for their time.

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Summary

A regional workshop on Nanomedicine -- Terminology and Standards was held on January 12, 2010 at the Chemical Heritage Foundation (CHF) in Philadelphia, PA. The Workshop was co-sponsored by the CHF Center for Contemporary History and Policy and the American National Standards Institute (ANSI) Accredited U.S. Technical Advisory Group (TAG) to the International Standards Organization (ISO) Technical Committee (TC) 229 on Nanotechnologies. The objectives of the Nanomedicine workshop were to:

1. Visit current concepts and categorizations of nanomedicine in order to identify pertinent and timely sub-categories for terminology purposes; and
2. Identify terms and challenges for populating those sub-fields.

Overall, 25 participants representing 21 organizations took part. Presentations were given on the ANSI-Accredited U.S. TAG and the work program of Joint Working Group (JWG) 1 on Terminology and Nomenclature. A presentation on informatics and ontological project development in the field of cancer medicine was provided to illustrate an informatics application for terminology development in an important nanomedicine subfield. Focused presentations were provided for objectives 1 and 2, respectively, followed by a break out session for Objective 1 and a group discussion in the case of Objective 2.

Introduction

ANSI and the CHF co-sponsored a regional workshop on "Nanomedicine -- Terminology and Standards" on Tuesday, January 12, 2010 at CHF headquarters in Philadelphia, PA. Participants examined applications of nanotechnology in the medical field with attention to emerging terminology usage. The workshop was intended to support terminology activities within the ANSI-Accredited U.S. TAG to ISO TC 229 *Nanotechnologies* and may lead to proposals for standardization of terms.

Through its participation in ISO/TC 229, the ANSI-Accredited U.S. TAG is currently participating in projects in the field of nanomedicine. Existing ISO/TC 229 projects are pursuing terminology development in topical areas such as the bio-nano interface and terminology for health care professionals in nanotechnology. The January 12th workshop examined nanomedicine in the United States and how these activities may inform the efforts of the U.S. TAG to develop a framework for the development of Nanomedicine and terminology.

Terms are being used in the scientific literature such as "nanostructure-drug conjugate" and "nanobiomolecular vaccine". The U.S. TAG notes the presence as well of scientific journals such as "Nanomedicine: Nanotechnology, Biology, and Medicine" and "Nanotoxicology." ***Figure 1*** demonstrates that from 2000 to present the number of journal publications reporting on nanomedicine research is intensifying.

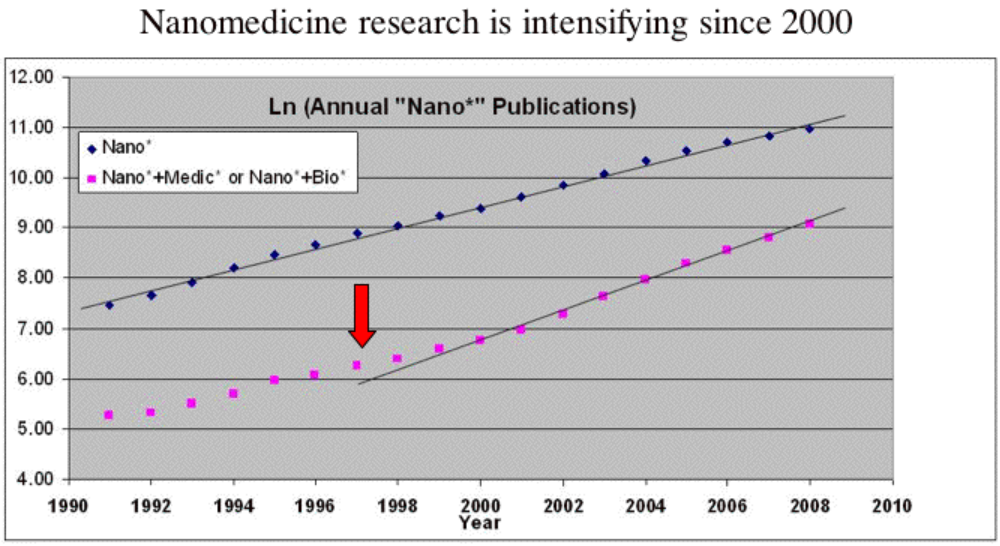


Figure 1: Number of journal publications reporting on nanomedicine research 2000 present.[*] Originally utilized in the NSF Workshop: "Re-Engineering Basic and Clinical Research to Catalyze Translational Nanoscience"

The workshop had a regional focus, intended to take advantage of the many firms, institutions and organizations with a focus in medicine. Invitees included experts who have published articles or patents mentioning nanotechnology in a medical context or have attended other conferences on the subject of nanomedicine. The primary objectives were to:

1. Visit current concepts and categorizations of nanomedicine in order to identify the more pertinent and timely sub-categories for terminology purposes; and
2. Identify terms and challenges for populating those sub-fields.

A secondary objective of the regional Workshop was to gauge interest in and need for consensus development of terms for use by academia, industry, government and societal groupings.

[*] This image was published in Nanotechnology, Biology and Medicine, Vol. 5, Murday, J.S., Siegel, R.W., Stein, J. Wright, J.F., Translational Nanomedicine: Status and Opportunities, Nanomedicine, pp 251-273, Copyright © Elsevier 2009

Nanomedicine Segment – Presentation

Though the term “Nanomedicine” is used by the scientific community and government agencies, the scope of the field remains relatively undefined. It is expected that this field will expand greatly as advances are made in utilizing nanotechnology for drug delivery, diagnosis and patient monitoring.

Those sub-fields most pertinent to the activities of ISO/TC 229 and having a community of practitioners willing to undertake the work will be identified and a framework proposed for addressing the sub-fields in an appropriate order. Potential sub-categories of medicine to be examined may include diagnostics, therapeutics, regenerative medicine, prosthetics, public health, toxicology, point of care monitoring, nutrition, medical devices, prosthetics, biomimetics, and bioinformatics. This is a very broad potential scope that may be narrowed as it becomes more clear which of those aspects of medicine are particularly impacted by nanotechnology.

The segment began with an introductory powerpoint presentation on nanoscience and nanotechnology. This presentation highlighted that nanoscale material properties are transitional from molecular to bulk material characteristics and may present chemical and particle/ultrathin film properties simultaneously, reflecting the prominence of surfaces and the emerging collective behavior of the components. The whole of nanoscience and nanotechnology is not vertical; it is horizontal and merges with a number of medical disciplines. Definitions in the field are fluid. Public definitions are influenced by articles that appear in the print media or on the Internet and scientists responding to new research observations are continuously creating new definitions that fit their research field. Meanwhile, funding agencies and policy makers also generate their own decision-enabling definitions. While collecting and cataloging the emerging public, scientific and governmental definitions has its own merit, there are public policy needs for a more standardized terminology and nomenclature, as was demonstrated in a case history discussion at the Workshop.

Nanomedicine Segment – Breakout Session

Participants were asked to provide an overview of fuctional categories of medical fields identified as promising for nanomedicine. As a starting point, workshop attendees were presented with a structural diagram based on a handout of proposed categories for consideration prepared by workshop organizers (C.1) and a diagram of application categories of nanomedicine published by Freitas (1999) (see Appendix C.2). Participants were asked to consider the three following questions:

- Do participants agree with the method of organization or would you recommend an alternative representation?
- Do participants agree with the structural relationship or would you establish different relationships among the sub-fields presented?
- Can participants identify any missing elements?

Case Study – Usage in NanoMedicine, Nanotechnology, Biology and Medicine

This case history involved reviewing the key word list from the publication *NanoMedicine: Nanotechnology, Biology and Medicine* that is used to communicate results in the field from 2006-present. This list is provided as Appendix B and may serve as a reference for compilations of relevant terminology. To create useful and searchable nanomedicine terms, workshop participants discussed the value of linking "nano-" terminology to an existing medical classification system. A possible choice is the National Library of Medicine's controlled vocabulary thesaurus, known as "MeSH" (Medical Subject Headings). MeSH is an online searchable database that consists of sets of terms and descriptors in a hierarchical structure that permits searching at various levels of specificity. MeSH descriptors are arranged in both an alphabetic and a hierarchical structure. At the most general level of the hierarchical structure are very broad headings such as "Anatomy" or "Mental Disorders." More specific headings are found at more narrow levels of the eleven-level hierarchy. There are 25,186 descriptors in 2009 MeSH. There are also over 160,000 entry terms that assist in finding the most appropriate MeSH Heading, for example, "Vitamin C" is an entry term to "Ascorbic Acid." In addition to these headings, there are more than 180,000 headings called Supplementary Concept Records (formerly Supplementary Chemical Records) within a separate thesaurus. The U.S. National Library of Medicine is the creator, maintainer, and provider of the data. MeSH, in machine-readable form, is provided at no charge via electronic means. The MeSH Web site http://www.nlm.nih.gov/mesh is the central access point.

With regard to method of organization and structural relationships between sub-fields of nanomedicine: Two of the breakout groups proposed similar methods of organization; one group chose to respond to the structure and information in the handout, and one group presented an alternative structure of organization.

Case Study - Continued

A review of the MeSH descriptors indicates that nanomedicine may be having a significant effect on only certain subfields of medicine (e.g. drug delivery devices are one such area of significant activity) at this time. However, it is expected that terminology usage will continue to evolve as the medical community absorbs new developments and input categories for the NLM. The NLM MeSH database provides transparency to users by showing how the database evidences this migration of catagories over time. As previously noted, it may be desirable to achieve better consistency between the usage of key words in nanomedicine terminology journals and the MeSH database.

Group 1:

(1) Prevention → (2) Diagnosis → (3) Treatment as a general stages in arriving at a medical decision to be combined with sub-buckets of (a) imaging, (b) materials, (c) delivery systems and (d) instrumentation for each stage.

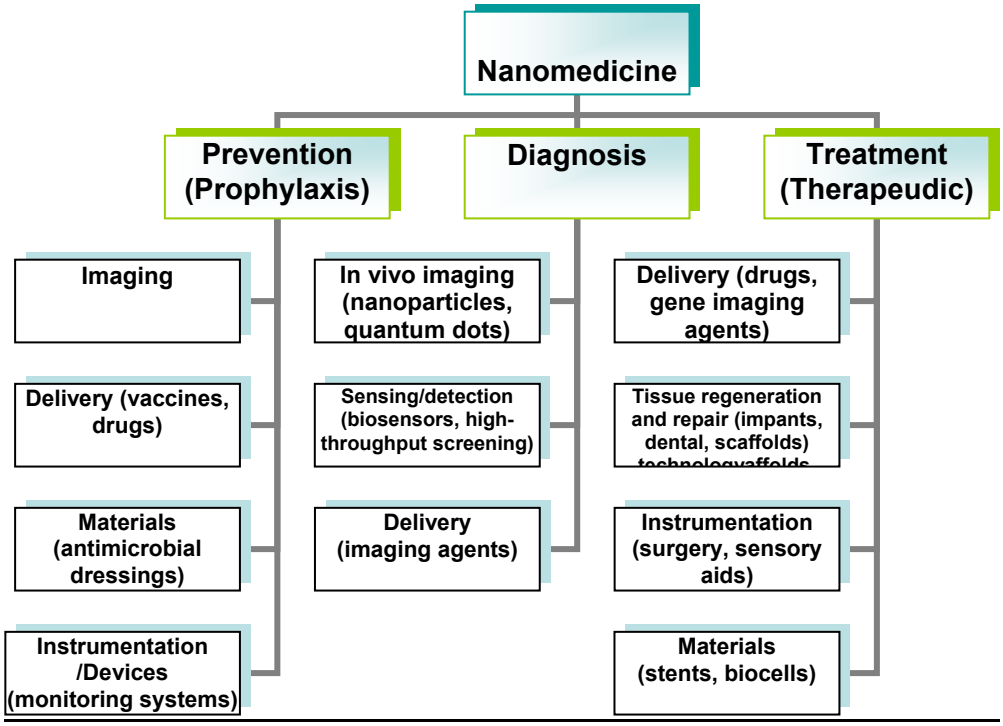


Fig. 2. Nanomedicine Workshop Breakout Group 1

Group 2:

(1) Prediction → (2) Prevention → (3) Diagnosis → (4) Treatment → (5) Monitoring (follow-up) as the stages of a value chain decision process with two questions asked at each stage: What is the objective? and, What are the supporting technologies (hardware and software) ?

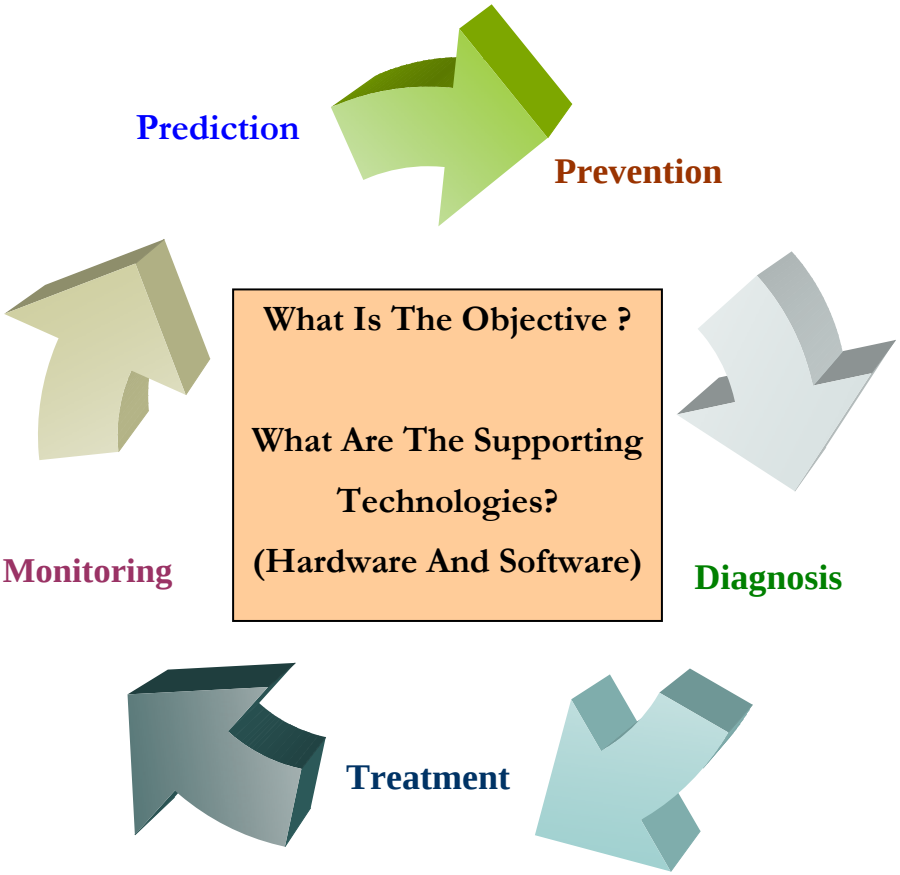


Fig. 3. Nanomedicine Workshop Breakout Group 2

Group 3:

An alternative categorization of the medical field where the categories are: Therapy, Sensing, Delivery, Imaging, Diagnosis, and Disease Treatment where it may be possible to reduce toxicity, reduce physiological barriers, and improve efficiency.

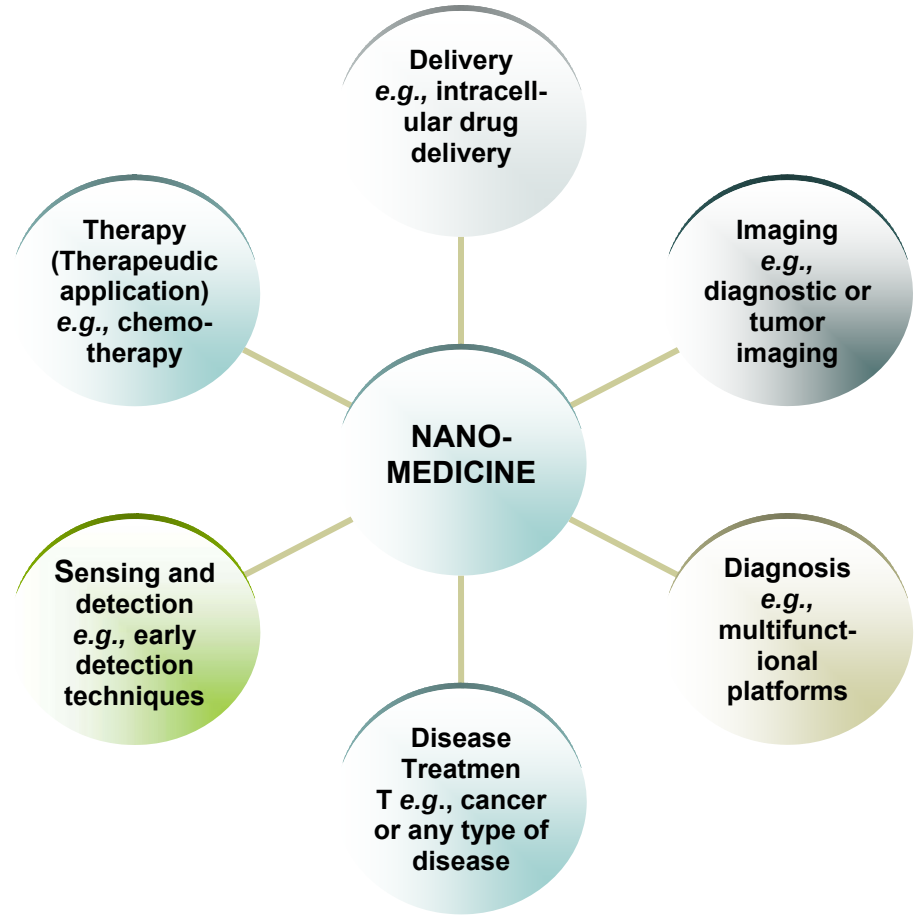


Fig. 4. Nanomedicine Workshop Breakout Group 3.

Group 4:

This group recommended adding drug discovery as an independent topic, drilling down to finer aspects of functionality for many of the topics in the handout and adding cross-disciplinary support as an independent topic. Translation and migration of nanomedical-related technologies from basic research to clinical applications is anticipated. On both sides, information theory includes consideration of how the information gained is used for decision making. Application areas include implants, tissue repair and regeneration, and drug discovery and delivery. Supporting core technologies are viewed as sensors (detection, quantifitation, and characterization), structures and instruments (surgical aids), and devices, machines (point of care monitors) or self-assembling systems.

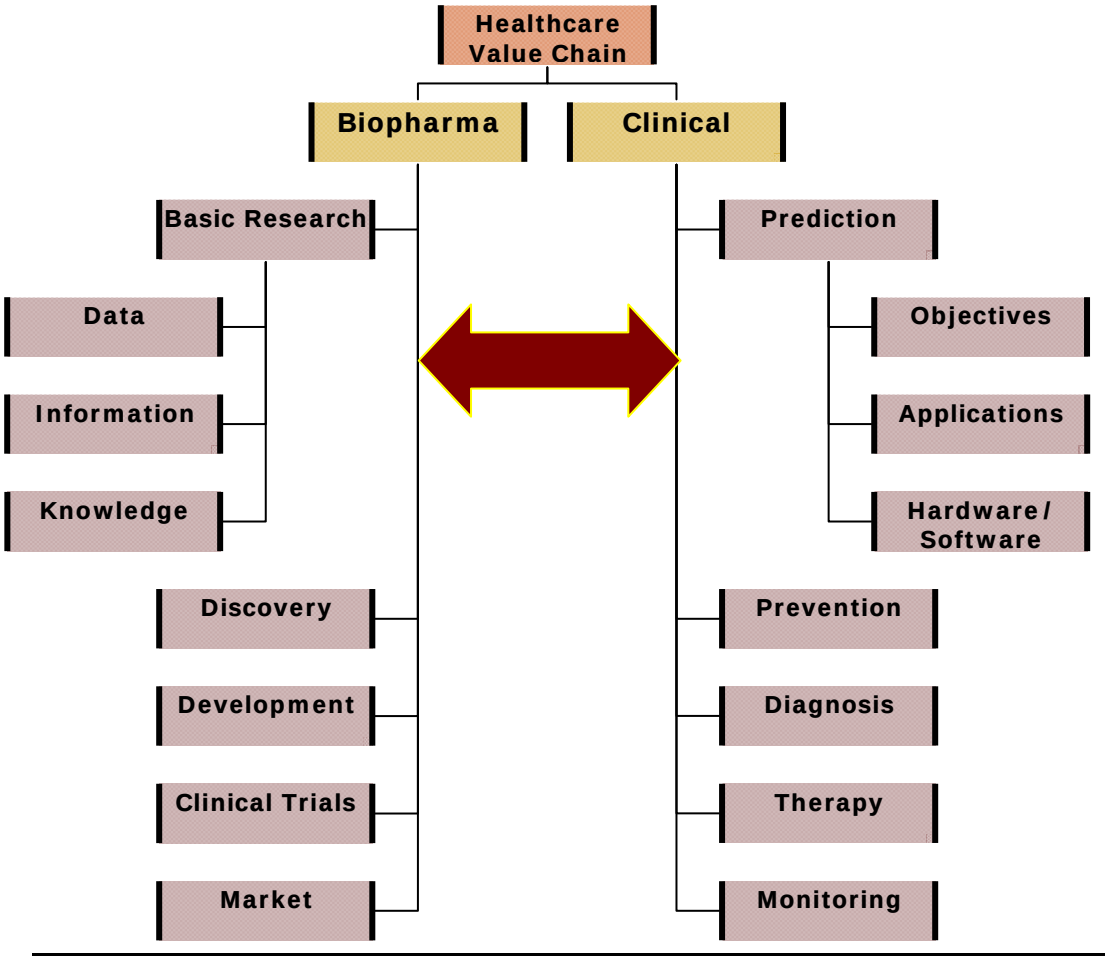


Fig. 5. Nanomedicine Workshop Breakout Group 4.

Group 1 and Group 2 represent, respectively, the medical practitioner's training and the value chain evaluation process a firm might take in making an investment decision. Group 3 represents an alternative ontology. A terminology framework exercise would consider these approaches in establishing a working system for setting priorities. A variant of the medical and company decision-oriented process might be developed for terminology requirements that are then applied to the specific fields found in the amended handout/alternative proposals.

Concerning missing elements, drug delivery was identified as a missing element in current depictions, and was felt by participants to be the area of medicine most currently affected by breakthroughs in nanotechnology. One group in the breakout session commented on there being a value to using the drug discovery "journey" as one means of looking over the field.

During the breakout session, participants explored the subject of stakeholders. Experts examined the "who" and "why" for the need for terminology. Needs identification was explored among scientists, engineers, materials scientists, and information management specialists. The following stakeholder categories were established: the developers and users of technology, deliverers of medicine, and the process overseers. Further discussion clarified the term "process overseer" included members of the regulatory community. Those likely to work on development of a common terminology should understand the level of interest and potential use that would be made by governmental agencies responsible for funding research (interest of the academicians) and responsible for regulation (interest of the commercial firms). There was no resolution of an appropriate time table for developing a common terminology for nanomedicine. The participants in the breakout session recognized these and other values associated with a standardized terminology and framework.

Terminology Session – Presentation Summary

An overview was presented of the relationship between standard terminologies in informatics for nanomedicine. Lexical semantics, the meaning of words when combined into sentences and phrases, will differ among groups and it is both prudent and valuable to retain these nuances (metadata) when conducting broad spectrum keyword searches. Namespaces and scientific disciplines with a set of core concepts and relationships relevant to the Workshop topic were presented as: (1) Nanomaterial design and synthesis; (2) Chemical interactions; (3) Physical interactions; (4) Biological Interactions; (5) Clinical Testing Medical Applications; (6) Environmental toxicology and (7) Human safety, exposure. Each of these areas faces challenges (gaps in data or conceptual frameworks) when deriving structure-activity relationships to use with nanotechnology. Examples of on-going informatics efforts were given for open-format, federated data base efforts including Nanotechnology Particle Ontology (NPO), cannibal, cabin, Biomed, nano-OM and nano-WG.

Terminology Session – Group Discussion

Overview

Participants were asked to respond to a series of questions during this discussion phase. As a starting point, a compilation of published terms accompanied by a handout prepared by workshop organizers were provided to workshop participants. The compilation of terms was sourced from a review article that was used as a basis for designing this portion of the Workshop, "Translational nanomedicine: status assessment and opportunities," James S. Murray, Richard W. Siegel, Judith Stein, J. Fraser Wright, Nanomedicine: Nanotechnology, Biology, and Medicine 5 (2009) 251–273.

Question 1 explored the relative merits of *bio, bionano, nanobio and nano* when modifying root nouns such as material. A specific example was given of reinforced polymer using a 30 nm nanoparticle mesh for organ repair procedures. Responses indicated no strong preferences with a general acceptance that the field of origin (a biological discipline or a nanotechnology one) may determine which of these prefixes is preferred. One participant selected the term biocompatible nanomaterial as the most specific and self-explanatory option, and the suggestion was made to utilize the context of the historical size-based description of biology, namely, biology, microbiology and photobiology.

Question 2 contrasted size relationships in biological systems to the approximately 100 nanometer (nm) upper boundary found in the ISO definition of the term "nanoscale". The term nanoscale comes from materials science and expresses in part the size range associated with quantum effects. In this case, responses indicated that mechanisms associated with diagnosis and treatment in biological processes such as endocytosis may be larger than approximately 100 nm. Several participants from the biological sciences have worked with 400 nm diameter particles as drug carriers, while others have considered break points of < 1000 nm or < 500 nm as pertinent. In additional comments, the ecosystem, cellular system and molecular system categorization of biological processes was identified for consideration in a framework exercise.

Question 3 examined the established use of terms in regulatory contexts and asked how

regulatory considerations affect the pursuit of terminology. Responses followed along the lines of the earlier breakout discussion concerning stakeholders, with those familiar with internal processes at regulatory agencies speaking in favor or establishing a terminology with a focus on scientific considerations distinct from considerations associated with regulation. Others felt that it was important to be alert to the needs of coordination associated with terms having strong legal implications, and encouraged greater interactions with regulatory agencies and international participants, for whom English is a second language.

Question 4 explored the use of the term *nanostructure* in biological contexts and contrasted it against the current definitions of nanostructure in TC 229. Responses were varied. In terms of shapes, there may be too many structural motifs to serve as a meaningful basis to capture in a lexicon. The term *nanosome* was not viewed as carrying the degree of communication value or the meaning associated with the term liposome. Domain (specific region of biological significance) was viewed as an appropriate concept for discussions concerning protein molecular structure and cell membrane structural organization. Region (area or real estate) seemed less appropriate to biological discussions and more relevant to materials science structures. Hard and soft material concepts were repeatedly raised throughout the day as a concept for expressing nanotechnology developments in medicine, and are seen as reflecting flexibility of a material.

Question 5 asked if established terms that do not have the nano-prefix should be addressed in a nanomedicine terminology document. Responses tended towards the affirmative if the term is descriptive of a nano-object interacting with a biological molecule, *e.g.*, conjugate.

Question 6 considered functionalization of nano-objects contrasted with modes of action resulting from this functionalization. There was general acceptance that there were three modes of action: inert (passive); self-contained activity (responsive to externally applied stimulus) and responsive to variations in biological processes. It was observed that there may be biological responses to a nano-object whether or not it is viewed as passive, self-contained or responsive.

Question 7 explored cell entry mechanisms, endocytosis, affected by nanoparticle functionalization and surface properties. Participants indicated a preference for focusing on describing the attributes of the nano-object that influence membrane interactions. It was noted that the materials scientists tended to describe a nanoscale material starting at its center, while biological scientists begin with a description of the external surface molecules species.

Question 8 An initial listing of 18 terms (5 general, 13 collected into three categories) was presented in a tentative framework as follows:

Framework	***Proposed Terms***
Field	Nanomedicine
Sub-field	pharmacology/nanopharmaceutical
Sub-field components	components of a nanopharmaceutical (active, adjuvant, excipient, device, etc)
Nanoscale component	nanocarrier or bionanomaterial
Nanostructure functionality	modes of action (passive, self-actuated, responsive
Nanoscale component design:	nanostructure shapes (nanoshell, nanocore, hard material, soft material)
Surface topography	nanotextured
Surface species bound to the nanoscale component	types of binding (corona, protein corona, nanoparticle conjugate, decorated, stealth, embedding).
Targeted functionality:	affinity (to the specific target)

Figure 6. Elements and Terms Presented for Consideration in a Terminology for Drug Delivery

The terms listed in the right hand column of Figure 6 above were intended to respond to the following inquiries: Is a nanoscale component present? What is its purpose? Is it functionalized? Is it targeted? As an illustrative example, a simplistic structural description of a nanoscale component arising from these terms would be: (1) nanostructure shape, (2) adsorbed or chemically bonded surface species, (3) decorated with (4) protein functionalities that target cell membrane receptors and/or membrane lipid constituents (such as “lipid rafts”). The term “decorated” was used during these

discussions to express the surface species. Another participant proposed “nanosensor” as an additional term.

As noted above, the listing of terms was rational in terms of the questions and did not evoke any strenuous objections. The discussion phase of the Terminology Session illustrated a preference in the field for exploring nanotechnology terminology through consideration of specific applications (bottom up) rather than from a strictly sub-field identification basis.

Overall Workshop Summary and Observations

It is hoped by participants that the results of this successful workshop will be useful for establishing interest and needs identification for terminology development in the field of Nanomedicine to support the work of the ANSI-Accredited U.S. TAG to ISO/TC 229.

Observations from the workshop include the following:

- The Workshop highlighted the ambiguity of terminology, identified several stakeholders and their needs, and indicated that certain aspects of medicine are being impacted by nanotechnology.
- The fluid use of terms by the public and by individual scientists warrants standardization for the purposes of communications and public policy.
- It is likely that nanomedicine terms will be generated from diverse disciplines. For example, the physical chemist’s substrate, a material surface supporting adsorption processes, differs from the biologist’s substrate of a substance for activating an enzyme’s function.
- In the discussion about stakeholders, agency funding interests were prominently referenced by the participants as an area in need for consensus understanding of terminology.
- Regulations were prominently referenced by participants as an area in which terminology will be adapted and utilized.
- Participants felt it will be useful to explore coordination and collaboration on an international level with the pharma, research, and medical communities.
- Considerations should be given to additional regional workshops and further discussions on this topic.

- It is envisioned as a next step that a new work item proposal will be put forward by the ANSI-Accredited U.S. TAG to ISO/TC 229 *Nanotechnologies,* and that participants in this workshop will be invited to consider providing their expertise in the development of this international document.

Appendix A: Workshop Agenda

Nanomedicine Terminology Workshop

12 January 2010
10:00 a.m. to 4:15 pm

Chemical Heritage Foundation
315 Chestnut Street
Philadelphia, PA 19106

1.0 Welcome and Opening Remarks
10:00 a.m. to 10:05 a.m.

Dr. Tom Tritton
Chemical Heritage Foundation

2.0 Welcome
10:05 a.m. to 10:10 a.m.

Dr. Clayton Teague
ANSI-Accredited U.S. TAG to ISO/TC 229 Nanotechnologies

3.0 Introductions
10:10 a.m. to 10:20 a.m.

Experts will introduce themselves and provide background as to their interest and/or experience relative to nanomedicine

Dr. Fred Klaessig
Pennsylvania Bio-Nano Systems, LLC

4.0 ANSI and the Voluntary Consensus Standards Process
10:20 a.m. – 10:35 a.m.

Ms. Benko will provide an overview of the American National Standards Institute (ANSI), the American National Standards (ANS) process, and their interest in this initiative.

Ms. Heather Benko
American National Standards Institute

5.0 Presentation: ISO/TC 229 Terminology and Proposed NWIP
10:35 a.m. to 10:50 a.m.

Ms. Marrapese will provide background regarding the establishment of this workshop, workshop themes, and a New Work Item Proposal (NWIP) to be submitted to ISO/TC 229 Nanotechnologies on a Framework for Nanomedicine Terminology.

Ms. Martha Marrapese
Keller and Heckman

6.0 Presentation: Nanomedicine
11:05 a.m. to 11:30 a.m.

Dr. Lajos Balogh
Editor-in-Chief,

An overview of Nanomedicine and commentary on current activities and the range of U.S. interests.

NanoMedicine: Nanotechnology, Biology and Medicine

7.0 Discussion Theme: Medical Sub-fields most affected by Nanotechnology.
11:30 a.m. to 12:30 p.m.

Participants will review three visualizations of the sub-field of Nanomedicine and discuss adjustments to reflect current knowledge.

Dr. Lajos Balogh, Moderator

8.0 Recap of Morning Session
12:30 p.m. to 12:45 p.m.

Ms. Martha Marrapese

9.0 Review of Afternoon Theme
1:30 p.m. – 1:45 p.m.

Dr. Fred Klaessig

10.0 Presentation: USA Activities in Bioinformatics
1:45 p.m. to 2:15 p.m.

An overview of current terminology databases under development related to nanomedicine and the benefits of common usage of terminology to advance scientific development.

Dr. Martin Fritts
National Cancer Institute Nanotechnology Characterization Laboratory

11.0 Discussion Theme: Medical Terminology most affected by Nanotechnology.
2:15 p.m. to 3:30 p.m.

Utilizing public review articles on nanomedicine, participants will discuss a list of terms used in Nanomedicine in relation to their prevalence and the potential for overlap with terms used in regulatory or other fields.

Dr. Fred Klaessig

12.0 Recap of Afternoon Session
3:30 p.m. to 3:45 p.m.

Ms. Martha Marrapese

13.0 Next Steps and Expected Outcomes
3:45 p.m. – 4:00 p.m.

Report out of Workshop, outreach, and related follow-up activities will be discussed.

Ms. Martha Marrapese
And Dr. Fred Klaessig

14.0 Closing Remarks and Adjournment
4:00 p.m. — 4:15 p.m.

Dr. Jody Roberts
Chemical Heritage Foundation

Appendix B:
Top 100 Terms in Nanomedicine Scientific Literature Survey

Keyword	*Count*
Nanoparticles	18
Drug delivery	11
Atomic force microscopy	12
Chitosan	6
Nanomedicine	5
Nanotechnology	5
Toxicity	5
Confocal microscopy	4
Controlled release	4
Doxorubicin	4
Molecular imaging	4
Nanoparticle	4
Tumor targeting	4
Apoptosis	3
Cancer	3
Gene delivery	3
Gold nanoparticle	3
Gold nanoparticles	3
Liposomes	3
Magnetic resonance imaging	3
Tissue engineering	3
Transfection	3
Amphotericin B	2
Antibacterial	2
Biodistribution	2
Bionanotechnology	2
Biosensor	2
Carbon nanotubes (CNTs)	2
Commercialization	2
Cytoskeleton	2
Dendrimers	2
DNA	2
Drug release	2
Glycation	2
Hyaluronic acid	2
Multiple myeloma	2
Nanobiosensor	2
Peptides	2
Phage display	2

Photocatalyst	2
Plasmon resonance	2
Polymeric micelles	2
Self-assembling peptide	2
Silver nanoparticles	2
Streptavidin	2
Young's modulus	2
198Au	1
1H HR-MAS NMR	1
2-diethylaminoethyl (DEAE)-dextran-MMA graft copolymer	1
3D architecture	1
A549 cells	1
Actin	1
Actin cytoskeleton	1
Advanced health care	1
AFM tip nanoindentation	1
Ag nanoparticle	1
Age-related diseases	1
Aggregation	1
Aging epithelial cells	1
Agonists	1
All-ceramic prostheses	1
Amino silica nanoparticles (NH2SiNPs)	1
Amorphous silicon nanostructure	1
Amyloid fibrils	1
Antibacterial activity	1
Antibiotics resistance	1
Antibody-conjugated nanoparticles	1
Antigen display	1
Anti-glycating agent	1
Anti-HIV	1
Anti-inflammatory	1
Antimicrobial delivery	1
Antimicrobial effects	1
Antimicrobial multimeric peptides	1
Antisense oligonucleotides	1
Antisense oligonucleotides (anti-ODNs)	1
Antisense therapy	1
Anxiolytic effect	1
Apatite	1
Architecture	1
Arteriosclerosis	1
Articular cartilage	1

Artificial cell	1
Artificial scaffold	1
Asymmetric unit membrane	1
Atropine sulfate	1
Autometallography	1
Azithromycin	1
Bacteria	1
Barrett esophagus	1
Bioavailability	1
Biochip	1
Bio-cloaking	1
Biocompatibility	1
Biocompatible	1
Biodegradable	1
Biodegradable polymer	1
Bioheat transfer	1
Bioimprint	1

Appendix C: Handouts for Nanomedicine Segment Breakout

C.1 List of Proposed Categories for Consideration

Assessment including diagnostics

- In vitro & in vivo diagnostic
- In situ diagnostic
- In vivo non-imaging
- Biosensors
- Point of care testing

Drug Delivery

- Constituents of a pharmaceutical preparation
- Implants for drug purposes such as NEMS
- Immunization

Implants:

- Orthopedic (structural)
- Dental
- Bioresobable materials

Tissue Repair & Regeneration

- Wound healing
- Dressings
- Tissue regeneration scaffolds

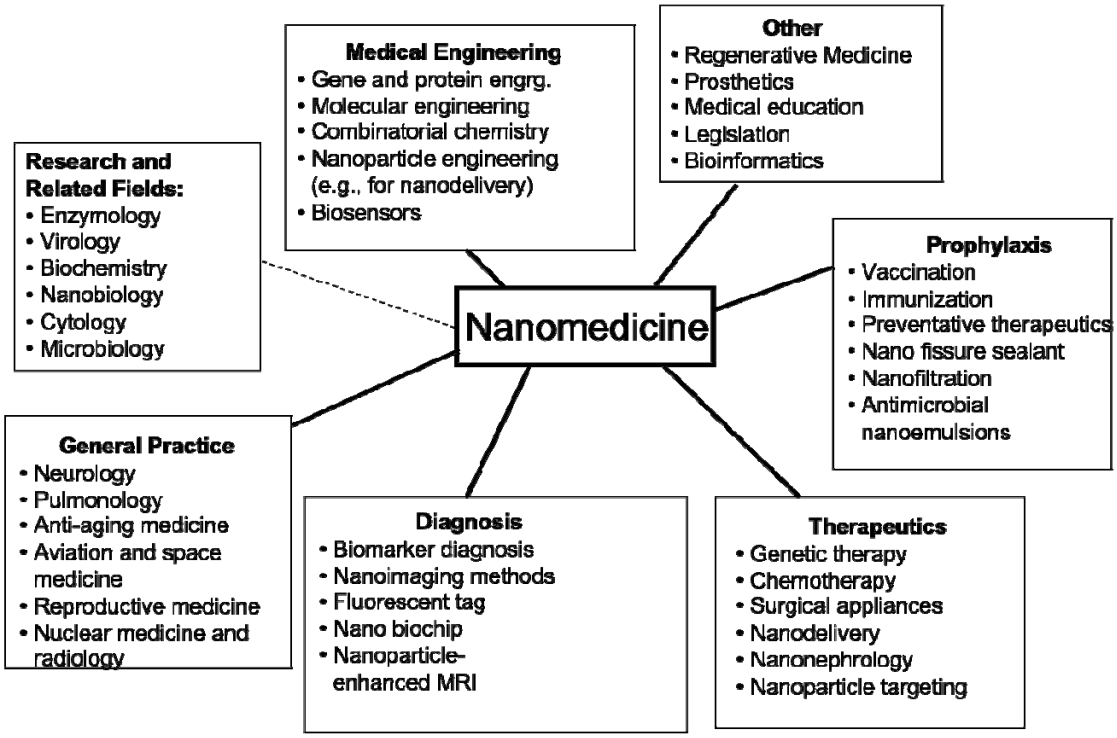
Drug Discovery

- Screening on non-cellular model systems
- In vitro and in vivo screening;
- Biopharmaceutics

Medical Instrumentation

- Surgical aids
- Point of care monitors
- Sensory aids (retina and cochlear)

C.2 Potential nanomedicine terminology framework



After: Frietas, Robert A. Jr., Nanomedicine Volume 1: Basic Capabilities, Landes Bioscience 1999.

Figure 7: Framework of Nanomedicine.[†]

[†] *After*: Robert A. Freitas Jr., Nanomedicine, Volume I: Basic Capabilities, Landes Bioscience, 1999 (http://www.nanomedicine.com). (c) 1999 Robert A. Freitas Jr. (www.rfreitas.com) All Rights Reserved. Used with permission