Problematic Design Paradigms

1) “Material-Mart”

- Materials are treated as “off the shelf” items with fixed characteristics.
- Little or no regard given to *processing-structure-property* relationships.
- Emphasis is on *functionality*.
- Driven (historically) by *physicians* and (in business) by the policies of the *FDA*.
- Examples: artifical heart, dialysis tubing, vascular grafts, breast implants, metallic orthopaedic impants, bone cement, etc.

Problematic Design Paradigms

"Being a chemical engineer, I had once thought that experienced chemical engineers or chemists were the driving force for bringing materials into medicine. But the closer I looked into that theory, the less I found it to be true. Rather, medical doctors were the ones who identified problems in their field and, urgently wanting to fix them, came up with materials solutions. They would search their surroundings–for example, their homes or local stores–to find objects that closely resembled the organ or tissue they wanted to fix. They would then adapt that material for use in the human body. While that practice has admittedly resulted in some solutions, it has also created problems."

- Robert Langer, *MRS Bull.*, **31**, 477-485 (2006)

Problematic Design Paradigms

"For example, in 1967 at the National Institutes of Health, some clinicians and engineers wanted to make an artificial heart. They started by asking, what object has a good flex life, like a heart? The answer they came up with was a ladies' girdle. They then determined that since the girdle was made of a polyetherurethane, they would make an artificial heart from that material. Today, 39 years later, we find that the artificial heart is still made of that same material—polyetherurethane. Yet, when blood hits the surface of the artificial heart (the ladies' girdle material), it can form a clot. That clot can then go to the patient's brain and cause a stroke, which could result in death."

- Robert Langer, *MRS Bull.*, **31**, 477-485 (2006)

Problematic Design Paradigms

"Similarly, dialysis tubing was originally made of sausage casing. The vascular graft, which is an artificial blood vessel, was developed by a Texas surgeon who searched for possible materials in a clothing store, based on what fabric would be easiest to sew. He chose Dacron. Of the two materials chosen for breast implants, one is a lubricant (silicone) and the other is a material used for stuffing mattresses (polyurethane)."

- Robert Langer, *MRS Bull.*, **31**, 477-485 (2006)

Problematic Design Paradigms

2) “Make it and break it”

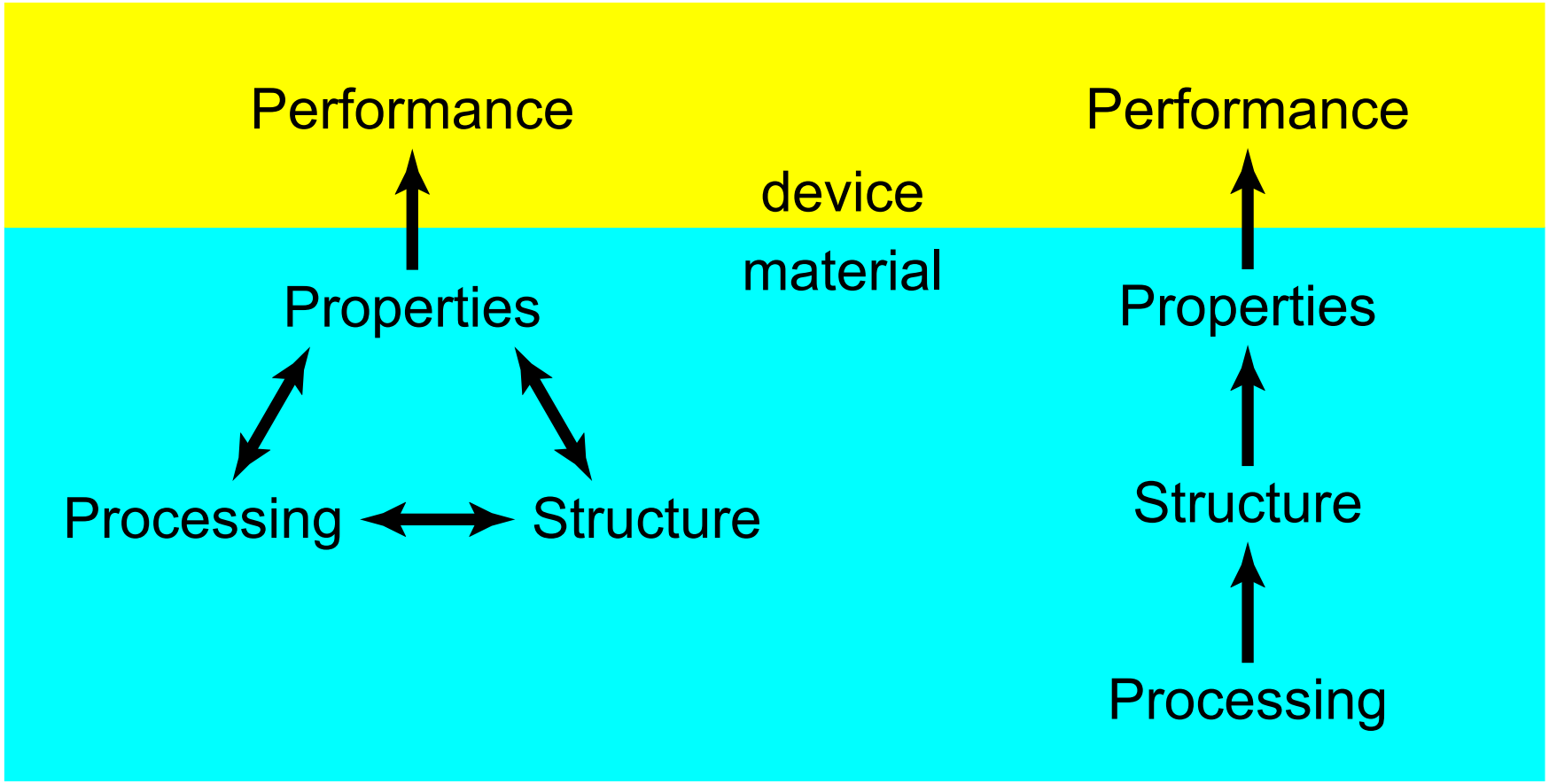
- Largely a “trial and error” approach.
- Little or no regard given material *structure*.
- Emphasis is on processing (new manufacturing methods) and performance, or “new” materials.
- Driven (historically) by *industry*, but also academics.
- Examples: titanium and porous metal orthopaedic impants, early development of dental and orthopaedic composites and bioresorbable polymers, nitinol stents.

Problematic Design Paradigms

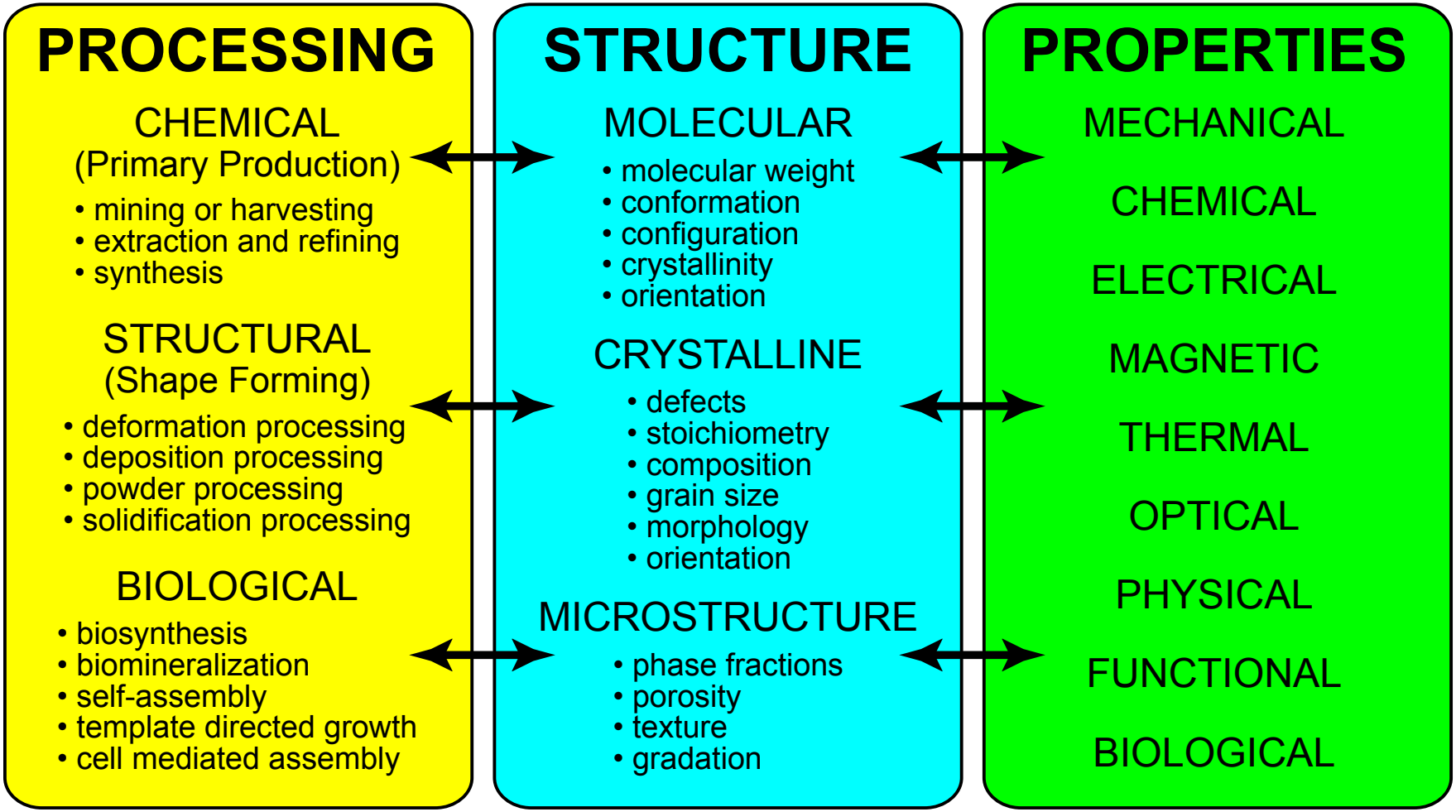
3) “Biomimetic”

- *Assumes* that the best way to achieve a desired outcome (function or performance) is the way nature has done it.
- Considers processing-structure-property relationships.
- Emphasis is on *mimicking* natural materials.
- Driven by *academic scientists*.
- Examples: early synthetic collagen, some synthetic bone graft substitutes, autografts and allografts, etc.

Materials Engineering Paradigm



Materials Engineering Paradigm



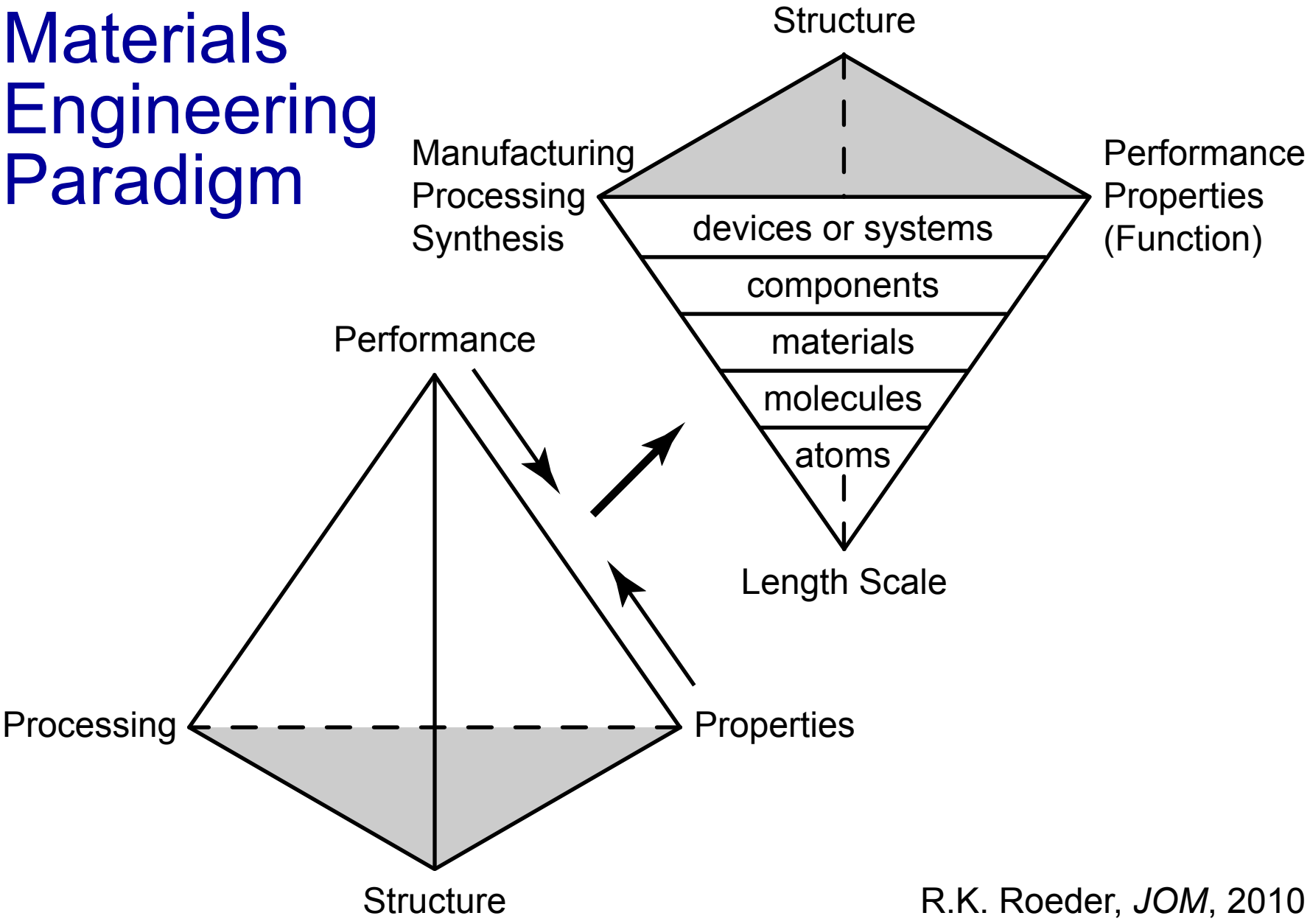
R.K. Roeder, *JOM*, 2010

Complicating Factors in Biomaterials ("Biocomplexity")

1) Biomaterials must replace or interface biological tissue.
   - Biological tissues are living.
   - Biological tissues adapt to a stimulus.
   - Biological tissues have hierarchical structure.

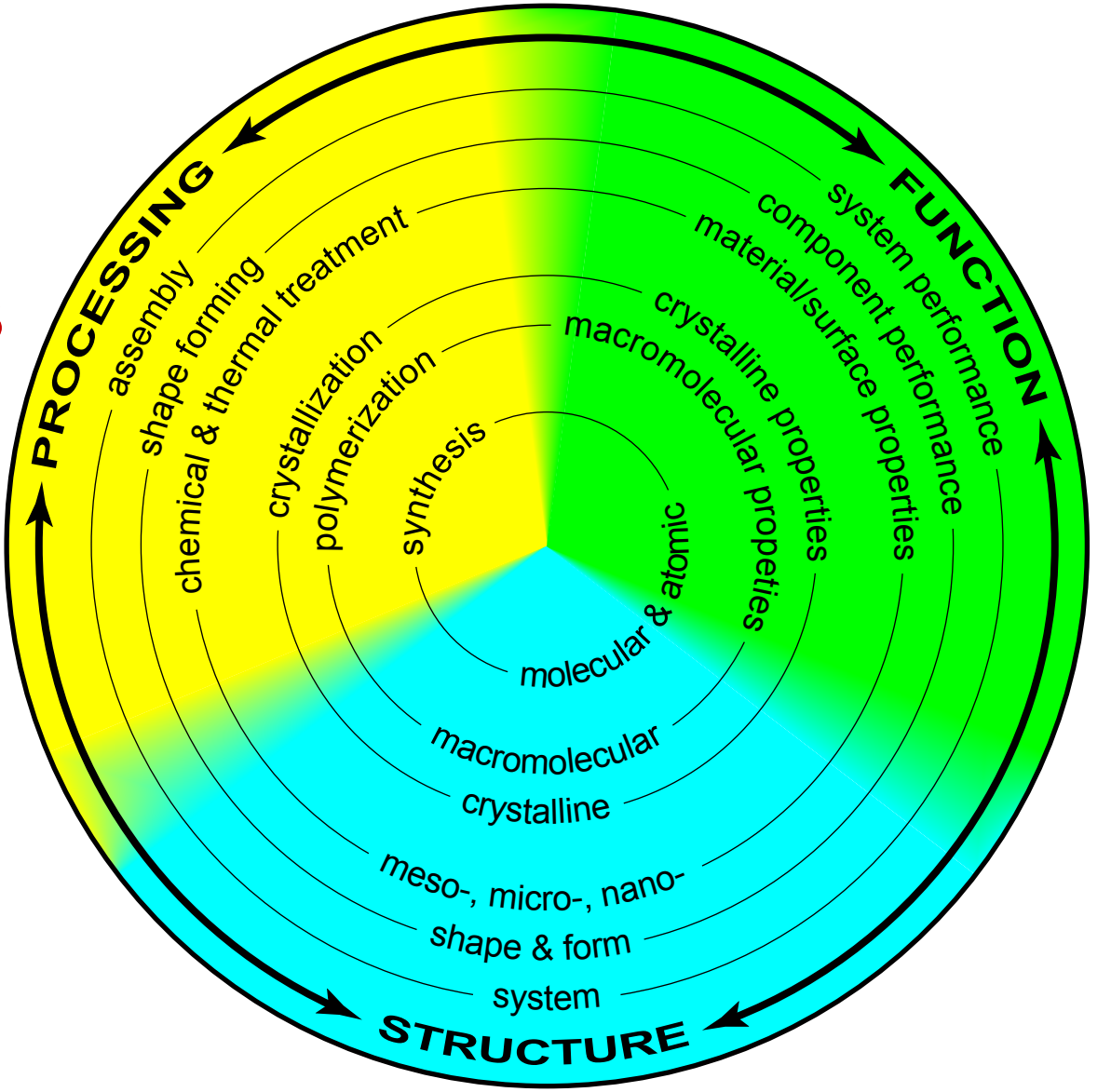
2) Biomaterials require great diversity among contributors.
   - Biologists
   - Chemists/Chemical Engineers
   - Mechanical Engineers
   - Materials Engineers
   - Physicians
   - and many others

Materials Engineering Paradigm



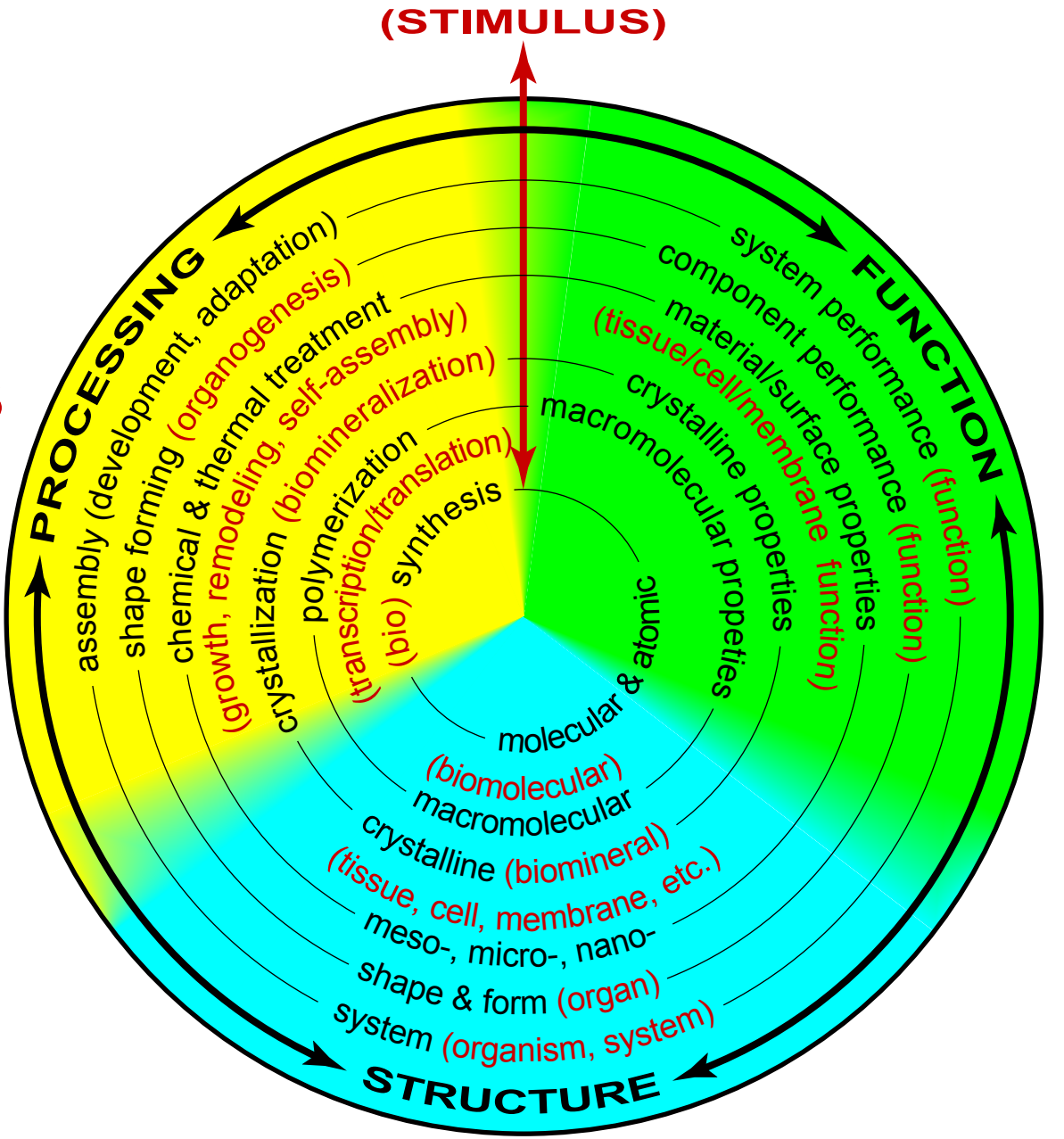
R.K. Roeder, *JOM*, 2010

Modified Materials Engineering Paradigm (with Parallels to Biology)



R.K. Roeder, *JOM*, 2010

Modified Materials Engineering Paradigm (with Parallels to Biology)



R.K. Roeder, *JOM*, 2010