three most prolific researchers – Vacanti, Langer & Mooney - acknowledge NSF funding on 19%-37% of their papers (that acknowledge research support). BS Kim, LG Cima, JA Hubbell, PM Kaufmann, CT Laurencin and WM Saltzman also acknowledge NSF on one-third or more of their papers. In contrast, NSF has had no role in supporting, amongst others, AI Caplan, LE Freed, VM Goldberg or G Vunjaknovakovic. And A Atala keeps his funding sources a secret.

C. A Note on Government Interest Patents

Among the tissue engineering patents were 19 which contained a statement of government interest. That is, the work underlying the invention had been declared by the inventors to have resulted from a government grant. Of these, NIH had 8, NASA 6, NSF 3, and DHEW 2.

VII. Co-authorship maps and tables

The depiction of co-authorship patterns undertaken in the final stages of the project does not lend itself to easy summary. In this type of work, the intellectual exercise is not aimed at compact verbal descriptions of salient features. Rather, novel graphics were developed to provide intelligible representations of extremely complex patterns, representations that do not distort the phenomenon nor so remove features in an effort at simplification that any deep understanding is precluded.

In this project, the lead authors' webs of coauthorship were portrayed in an innovative, multi-level system of tables and maps. Lead authors were defined as those with 10 or more core papers fundamental to tissue engineering. Three types of maps and tables are presented:

1. An overview map/table portraying links between lead authors

2. For each lead author (not included in a map), a table listing all coauthors, the number of papers collaborated on and the years in which joint work was published. Any NSF-supported work is noted. Finally, information useful for identifying PhD students of the lead author is included.

3. For authors who acknowledge NSF funding, detailed, paper-by-paper maps were produced that depict in some detail the development of the author's work in core papers and patents fundamental to tissue engineering. These maps are multi-dimensional and include: coauthorship, funding, topics, citations, and institutional affiliation. Exceptions to the rule that maps were drawn for lead authors who acknowledge NSF funding are that maps were not drawn for Langer, Vacanti and Mooney whose vast oeuvre and exceptionally interlinked coauthorship patterns precluded mapping using this technique which is best suited to in-depth portraits of smaller oeuvres.

A. Overview of lead author coauthorship patterns

Appendix 4 Tables D and E together display a high level overview of the publication pattern of lead authors. Lead authors are those with 10 or more papers who have produced some papers independently of Vacanti or Langer. Appendix 4 Tables F.1–F.22 display details on each lead author's coauthorships. Table E summarizes the interrelationships between the lead authors themselves. For each author and the author's papers in the analysis set, the figure displays:

- the first year in which a paper by the author appeared (1st year)
- the author's total number of papers (papers)
- the number of papers published before 1990 (pre-1990)
- the number of papers published every year between 1990 and 2001
- the number of papers acknowledging NSF support The number "2/1" means that of two papers in that year, one acknowledged NSF support.
- whether two authors worked in a permanent collaboration author ({)
- collaborative links with other lead authors (χ)
- collaborative links with Vacanti or Langer (⇨)

Table D provides a legend that explains how each of these elements is portrayed in Table E.

Table E successfully depicts the interrelationships between lead authors. The figure reveals that JP Vacanti and R Langer are prominent not just because of their highly cited *Science* paper, referred to above; not just because compared to any other lead author they have double or triple the number of papers in the set; but also because of the highly collaborative nature of their work. Nine of the other lead authors in this figure co-authored papers with Vacanti and/or Langer. Many of these might be PhD students who became established in their own right, including Mooney, Atala, Mikos and Ma. Mooney appears to have little independent work, but in fact in 1999 and 2000 most of his papers were not collaborative with either Langer or Vacanti and he should be considered independent. In a possibly 2nd generation relationship, Atala perhaps has established a PhD student – Yoo, whose substantial line of work so far is all collaborative with Atala. Caplan & Goldberg worked closely together during the 1990s, linking up with Bruder on occasion and working once with Langer in 1990. Boyan & Schwartz also form a permanent collaborative team. Others collaborated over shorter periods, for example, Yannas & Spector or Aebischer & Winn. Finally there is a set of authors not linked to any other lead authors, namely: Reddi, Green, Bell and Hansbrough.

B. Patterns of co-authorship

Appendix 4 Tables F.1-F.22 depict the full coauthorship pattern for lead authors. Again, lead authors are those with 10 or more papers who have produced some papers independently of Vacanti or Langer. The figures are ordered descending by total number of papers, so for example DJ Mooney with 53 papers is second (Table F.2), while PM Galletti with 10 papers is last (Table F.22).

For a lead author, each figure provides the following information:

- the first year in which a paper appeared (1st year)
- the total number of papers (collaborative papers)
- the number of papers by year

For each co-author and the co-author's papers in the analysis set, the figure displays:

- whether a co-author is also a lead author. If a co-author is also a lead author (i.e. with their own map or figure) *their name is in italics* and is right justified.
- the first year in which a paper by the author appeared (1st year)
- the number of papers the author produced in collaboration with the lead author (collaborative papers)
- the number of papers produced that were **not** collaborative with the lead author (other papers)
- for authors with more than one paper in the analysis set, an answer to the question: Was the author's first paper produced in collaboration with this lead author? (1st paper)
- the number of papers published before 1990 – individual years are displayed
- the number of papers published every year between 1990 and 2001
- the number of papers acknowledging NSF support. The number "2/1" means that of two papers in that year, one acknowledged NSF support.

Tables F.1 through F.22 again illustrate the dominance of R. Langer and JP Vacanti within the set of core papers fundamental to tissue engineering. Their eight page table lists over 250 coauthors. It subsumes substantial authors whose entire oeuvres, in this set of papers, are collaborative with either Langer or Vacanti including: CA Vacanti, B Schloo, LG Cima, J Upton, JE Mayer. BS Kim is another substantial work almost all of whose work is collaborative with DJ Mooney and/or JP Vacanti. LE Freed and G Vunjaknovakovic are on the borderline of this

category. The vast majority of their work is collaborative with R Langer, but they were treated as lead authors and a separate figure produced.

DJ Mooney is the subject of the second figure which lists 93 co-authors. Here we can see how his work from 1990 to about 1997 was closely associated with Vacanti & Langer, but after that he develops largely independently with another circle of coauthors developing including most prominently, BS Kim. Mikos (57 co-authors) and Ma (22 co-authors) seem to follow a similar pattern of early work closely linked to Langer & Vacanti, followed by independent work within a separate circle of coauthors.

As discussed above, other authors are less highly interlinked. Other authors with many co-authors are Wozney with 53 and Caplan & Goldberg with 45. Ingber worked for a few years in the early 1990s with Langer & Vacanti, but had produced papers in the area previously and continued publishing in the area afterwards. The large numbers of authors appearing on only one paper is a characteristic of science in general, and not specific to this set of papers.

C. Maps

Appendix 5 Figures A.1-A.6 are detailed maps of co-authorship and patenting for authors with a substantial component of NSF funding. Vacanti, Langer and Mooney are not treated in this way because the technique works only for smaller oeuvres. These paper-by-paper maps depict in some detail the development of the author's work in core papers and patents fundamental to tissue engineering. There are maps for: JA Hubbell, BD Boyan & Z Schwartz, CT Laurencin & HR Allcock, WM Saltzman, P Ducheyne, and RM Nerem.

These maps are multi-dimensional and include information on: coauthorship, funding, topics, citations, and institutional affiliation. The maps are essentially a matrix with authors/inventors in the rows and documents (papers or patents) in the columns. For each author, the documents co-authored/co-invented are identified. For each document, the authors/inventors are identified. Authors/inventors who appear on one document only are not individually displayed. Documents that acknowledge NSF funding are highlighted, and highly cited documents are noted. To the right of the maps are notes on institutional affiliations that focus on the leading authors on the map. The legend on each map explains the symbols and colors used. The maps are meant to be viewed in color. The maps are not meant to be read at a glance, rather they repay a little study and contemplation.

The first map concerns JA Hubbell who combines biomaterials with peptides to enhance cell adhesion and development. He has worked on both vascular and neural systems. Many of Hubbell's papers in the early 1990s at the University of Texas acknowledge NSF support, and two of these papers are highly cited by tissue engineering patents. This high citation rate may be largely due to Hubbell's own patenting with inventors at Focal, Inc. Seven patents were produced in this work, some of which are quite highly cited. Hubbell moved on to Caltech and now to ETH Zurich. His map illustrates the intermingling of public and private sector work in this area.

The same theme is seen on the map of BD Boyan & Z Schwartz. Boyan & Schwartz examine osteoblasts and chondrocytes regulating events in their extracellular matrix. The theme of private and public intermingling is continued here with co-patenting between the University of Texas and Osteobiologics. There is also patenting by the University of Texas alone. Here we see a lesser role for NSF funding, and less highly cited work as well.

On the map of CT Laurencin and HR Allcock, public and private knowledge are mingled, but only the public sector participates. Here we see both papers and patents acknowledging NSF support (that is, patents declaring that NSF has an interest in the work derived from its support of the research). Two of the patents are highly cited. There are three streams of Laurencin work in this map. The first is work in collaboration with HR Allcock that resulted in one patent. Allcock is a chemist who works on polyphosphazenes. Laurencin & Allcock worked on using polyphosphazenes in skeletal tissue replacement and this is the subject of their patent. Laurencin's second stream of work was with Attawia and Devin examining osteoblast growth on various scaffolds and this resulted in the two highly cited patents. The third stream brings in some NASA money and rotating bioreactors in the collaboration with Pollack and Levine.