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Was the 2012 Nobel Prize in Medicine Awarded for a Kuhnian Paradigm Shift?

An Author Co-citation Analysis Perspective

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Abstract

Stem cell research has been a fast growing, highly successful, and at the same time highly controversial field in recent years. Using a highly optimized author co-citation analysis methodology to study the intellectual structure of this field over the time period 2004–2009, we find that the induced pluripotent stem cell breakthrough that earned Shinya Yamanaka the 2012 Nobel Prize in Medicine did indeed quickly redefine its entire research field, and thus might truly qualify as a “paradigm shift” in Kuhn’s sense.

1 Extended Abstract

Recently, Strotmann/Zhao (2011) identified three major developments in the field of the international stem cell research field 2004–09 from an author co-

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citation analysis, by examining three two-year time slices (Fig. 1–3) – (a) the dying attempt of 2004–05 (Fig. 3) at a unified theory of “stem cell plasticity”, (b) the emergence of the cancer stem cell concept from medical stem cell research in 2006–07 (Fig. 2), and (c) the breakthrough that transformed the entire subfield of human embryonic stem cell research (2004–05: Fig. 3) to that of (human) induced pluripotent stem cells (2008–09: Fig. 1), a transformation linked to the phenomenal rise of Shinya Yamanaka.

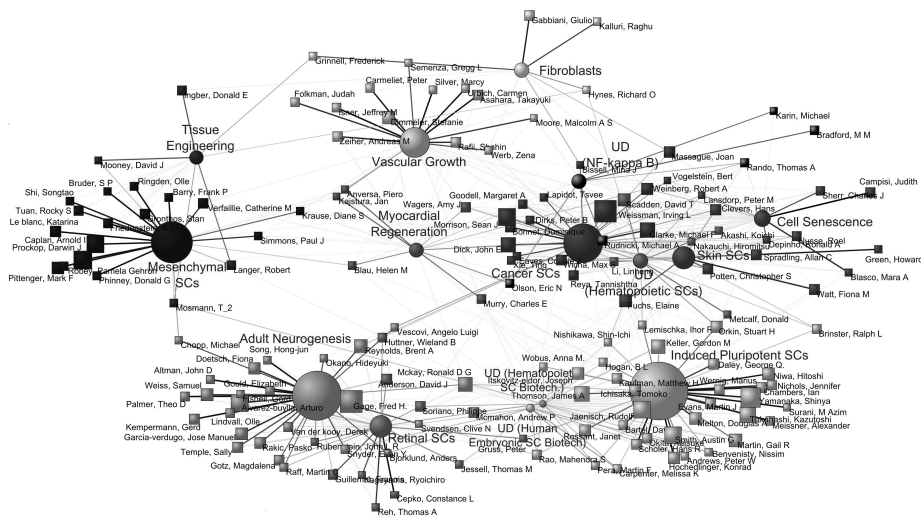


Fig. 1 Author co-citation analysis of the stem cell research field 2008/09

In 2012, the Nobel Prize in medicine was awarded to Yamanaka for having triggered, in his late 2006 publication, “a paradigm shift in our understanding of cellular differentiation” (Nobelprize.org 2012). And indeed, among the major changes in stem cell research we identified for this period, we see that the induced pluripotent stem cell breakthrough, (c), exhibits characteristics of a ‘paradigm shift’ in the popular sense, as human embryonic stem cell research appears to have shifted its entire focus to the study of induced pluripotent stem cells, in the remarkably short time of just a couple of years – unlike, for example, (b), the more ‘normal’ evolution of the successful cancer stem cell concept from medical stem cell research. This breakthrough was clearly linked to Shinya Yamanaka in our analysis, who exploded onto the scene between 2006 and 2009: not a highly cited researcher yet in 2004–05, he completely dominated this subfield (by citations received) by 2008–09.

As such, we find that bibliometricians could have spotted him from their data as a particularly likely Nobel Laureate, but any hope that they might be able in the future to accurately predict Nobel Laureates is simultaneously shattered by his co-laureate, whose prize-winning work had attracted only a tiny fraction of his co-laureates number of citations over several decades.

2 Methodology

The methods used to construct these visual maps of stem cell science extend those described in Zhao/Strotmann (2011). The data set used is identical. To recapitulate briefly, the data set is constructed by retrieving from PubMed records with MeSH heading “stem cells” and their cited references from Scopus, and performing automatic author name disambiguation on it.

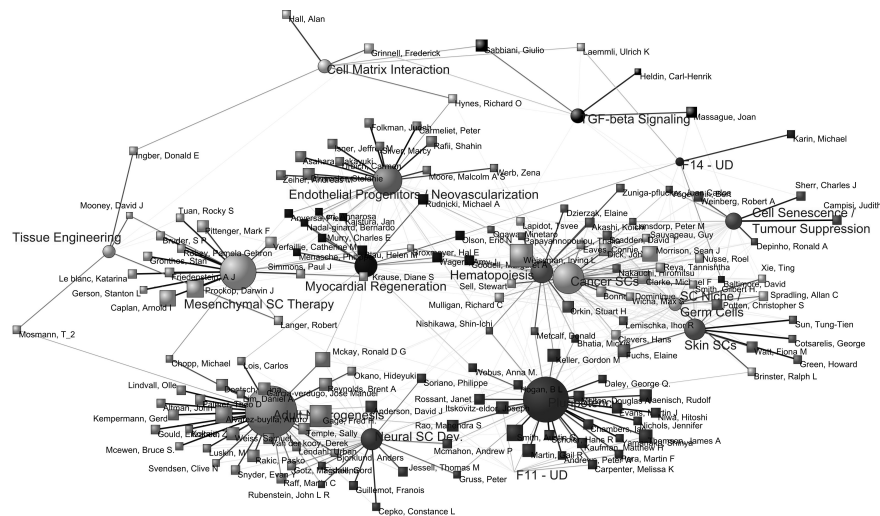


Fig. 2 ACA-Analysis of stem cell research literature 2006/2007

Except for different time slices, the method of analysis is also the same as in Zhao/Strotmann (ibid.) – an exclusive all-author co-citation analysis of the 200 most highly cited authors (by fractional count) in the stem cell research field in each time slice, using exploratory factor analysis with oblique rotation and with the number of factors to extract determined by Kaiser’s rule of

eigenvalue greater than one. Author loadings less than 0.3 are considered insignificant and discarded.

The visualization used here extends the one in Zhao/Strotmann (2008). It visualizes directly the results of a factor analysis, with authors as square, and factors (research specialties), as circular nodes. An author node is colored according to the factor that it loads most highly on in the pattern matrix result of the factor analysis. Node sizes are proportional to citations received (author nodes) or to the sum of member author citations, weighted by each author's loading (factor nodes). The visualization merges information on both the pattern and the structure matrix results of the obliquely rotated factor analysis, using the latter for automatic layouting (Kamada-Kawai algorithm in Pajek) and the former for gray-scale values of lines that link authors to the factors that they load on. Interpretation of the factor nodes (i.e., research specialties identified) proceeded exactly as in earlier papers, by manually examining highly co-cited papers of authors that load highly on a factor.

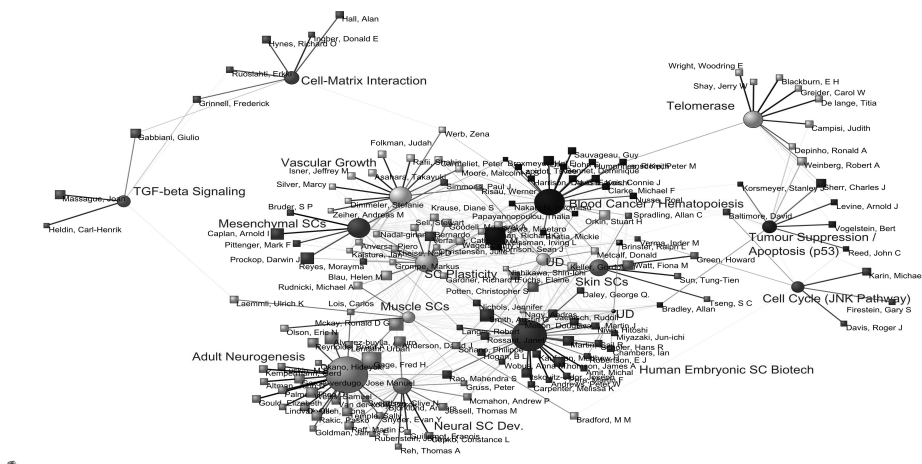


Fig. 3 ACA of stem cell research, 2004/05

3 Discussion

What makes research worthy of a Nobel Prize? This question has long fascinated many, but it is bibliometricians who have attempted to predict who among millions of scientists might qualify for this honor (Garfield/Malin

1968). While we do not answer this question in this paper, we do provide a partial characteristic: what made at least one researcher worthy of the Nobel Prize is that he initiated a “paradigm shift” (Nobelprize.org 2012) in a field recognized as important by the Nobel committee.

In an author co-citation analysis of the type we performed here, this paradigm shift is characterized, paradoxically, by a stable visual appearance of the affected research field in the visualization (the large, red or yellow, bottom-right factors in Fig. 1–3), accompanied by a shift in topic focus (factor labels). In this case, the initiator of the paradigm shift is the author whose node shows explosive growth in citations received within the area while the shift occurs. The success of the paradigm shift is seen from a rapid growth spurt of the shifting subfield relative to other subfields.

While we can see in our analysis that the Nobel Prize Committee is right in labeling Yamanaka a “paradigm shift” in the established sense of the word, their reference to textbooks having been rewritten suggests that they consider it a scientific revolution in the original sense of Kuhn (1970). Kuhn’s central criterion for a ‘paradigm shift’ is the incommensurability between old and new paradigms, as opposed to gradual change: Yamanaka essentially reverses the arrow of time in cell development biology – a dramatic change indeed.

Kuhn also posits a roadmap for scientific revolution: a crisis, which in this case came from ethical/legal problems of methodology rather than from science, followed by challenges from the established scientific community and re-establishment of coherence. “Textbooks (are) rewritten”, as both Kuhn and the Nobel Prize committee put it. What we see in Figures 1–3, and what is unusual in this particular paradigm shift, is that there was no challenge here: the whole field shifted in-place, fast. A blood-less scientific revolution.

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