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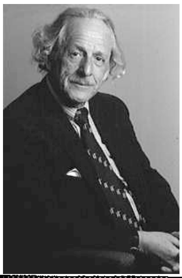

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Journal Citation Studies. 48. Developmental Biology Journals: Citation Analysis Demonstrates the Multidisciplinary Nature of Modern Embryology

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Developmental biology is the study of the developing organism, from fertilization and gestation through birth, growth, and aging. Originating in the nineteenth-century disciplines of embryology, comparative anatomy, and histology, developmental biology now also draws from such fields as biochemistry, molecular and cell biology, and genetics. Using ISI® citation data, this essay identifies the core and highly cited noncore literature.

In a previous essay we explored the literature of teratology, the science devoted to the study of birth defects, or developmental anomalies.[1] Teratology is a branch of developmental biology. This, in turn, is the study of the process by which a single cell (a fertilized egg) gives rise to the patterns and forms of organized masses of cells we recognize as tissues and organs. This includes not only macroscopic changes that occur at the organismic level, but changes at the cellular and molecular levels as well. The essential problem in developmental biology, according to Lewis Wolpert, Department of Anatomy and Biology as Applied to Medicine, Middlesex Hospital, London, UK, is to understand how this process is controlled by the genetic information contained in the egg.[2]

As in past journal studies, our primary aim is to identify the core journals of the field as well as the highly cited noncore journals of interest to the field. We also highlight the most-cited articles from the core journals of developmental biology.

Overview of Developmental Biology

Developmental biology originated in—and now subsumes—the science of embryology. Born in the mid-nineteenth century as an extension of comparative anatomy and histology, embryology is the study of the development of an organism throughout its life, from the stages of fertilization and gestation through birth, growth, and maturation.[3] The foundations of developmental biology were laid during the period 1885-1914.[4] One of the major advances during this time was the rediscovery of the laws of heredity that had originally been deduced by Gregor Mendel (1822-1884).[5,6]

There were many other pioneers, of course. A sampling includes Belgian biochemist Jean Louis Brachet (born in 1909), a specialist in nucleic acids in cell differentiation, whose most-cited article[7] has received over 240 citations. German zoologist Viktor Hamburger (born 1900) has written extensively in experimental neuroembryology; his most-cited paper[8] has received over 3,200 citations. US zoologist Ross Granville Harrison (1870-1959) developed the first successful animal-tissue cultures; his most-cited paper[9] has received over 240 citations. German embryologist Johannes Friedrich Karl Holtfreter (born 1901) has studied differentiation and specialization in animals; his most-cited work[10] has been cited over 170 times. French biologist Alfred Jost (born 1916), whose most-cited work[11] has received over 480 citations, has published extensively on fetal hormones. And French experimental teratologist and

Table 1: Core developmental biology journals indexed in the *SCI*® in 1986, with their editors, years of origin, publishers, and, where different, sponsoring organizations, and places of publication.*

Anatomy and Embryology (1877)
R. Bellairs, K. Fleischhauer, W.-G. Forssmann, W. Kriz, S.L. Palay & F. Walberg, eds.
Springer-Verlag
Berlin, Federal Republic of Germany

Cell Differentiation (1972)
International Society of Developmental Biologists
L. Saxen, ed.
Elsevier Scientific Publishers Ireland
Limerick, Ireland

Development (1953)
C. Wylie, ed.
Company of Biologists Limited
Cambridge, United Kingdom

Development, Growth & Differentiation (1950)
M. Yoneda, ed.
Japanese Society of Developmental Biologists
Tokyo, Japan

Developmental Biology (1959)
Society for Developmental Biology
P.J. Bryant, ed.
Academic Press
Orlando, FL

Differentiation (1973)
W.W. Franke, ed.
Springer-Verlag
Berlin, Federal Republic of Germany

Gamete Research (1978)
R.B.L. Gwatkin, ed.
Alan R. Liss
New York, NY

Placenta (1980)
H. Fox, ed.
Bailliere Tindall
London, United Kingdom

Roux's Archives of Developmental Biology (1894)
European Developmental Biology Organization
R. Weber, ed.
Springer-Verlag
Berlin, Federal Republic of Germany

Teratology (1968)
Teratology Society
R.L. Brent, ed.
Alan R. Liss
New York, NY

*Includes all superseded titles.

embryologist Etienne Wolff (born 1904), specialized in the *in vitro* culture of embryonic organs. His most-cited paper[12] has received over 495 citations.

Improvements in techniques, as well as the adoption of the methods of cell biology and genetics, helped change experimental embryology into the modern science of developmental biology. For instance, developmental biologists rearrange genes and chromosomes to observe the effect of the presence or absence of a specific sequence on development.[13] In this sense, developmental biology is very closely allied with the field of medical genetics, which deals with hereditary diseases.[14]

Developmental Biology Journals

Since Germany was the hub of embryological research from the mid-1800s until the 1930s, it is not surprising that the first journal devoted exclusively to experimental embryology was German: the *Archiv für Entwicklungsmechanik der Organismen*, founded in 1894 by Wilhelm Roux (1850-1924), University of Halle. Roux was among the pioneers of embryology, making important contributions as well as helping to publicize the field. In addition to the *Archiv*, he also produced two monograph series and introduced some of the field's terminology. "To the degree that he performed these tasks more zealously than his contemporaries," noted Frederick B. Churchill, Indiana University, Bloomington, in his biography of Roux, "he was the titular sire of modern experimental biology."[15]

After Roux's death, the journal he founded changed its name to *Roux Archiv für Entwicklungsmechanik* in his honor. Today called *Roux's Archives of Developmental Biology*, this journal is among the core publications for the field of developmental biology; the other nine journals are listed in Table 1. This list by no means includes every journal that publishes developmental research. The core journals were selected by consulting the *Science Citation Index*® (*SCI*®) and the *Journal Citation Reports*® and carefully examining the citation records of the journals listed under the heading "Embryology." With the advice of experts in the field, we determined the journals that predominantly cover *general* subjects in developmental biology and are most often cited by other developmental biology journals. Since this study focuses on journals, book series, such as *Current Topics in Developmental Biology*, were not included in this process.

Table 2: Most-citing developmental biology journals. The 49 journals that most frequently cited the core journals in 1986. Asterisks (*) indicate core journals. A=citations to core journals. B=citations to all journals. C=self-citations. D=percent of total citations that are core-journal citations (A/B). E=percent of total citations that are self-citations (self-cited rate, C/B). F=percent of core-journal citations that are self-citations (C/A). G=1986 impact factor. H=1986 immediacy index. I=1986 source items.

	A	B	C	D	E	F	G	H	I
*Develop. Biol.	2,689	12,258	1,735	21.9	14.2	64.5	3.63	0.97	346
*Development	1,508	5,238	647	28.8	12.4	42.9	2.61	0.63	161
J. Cell Biol.	672	22,727	—	3.0	—	—	8.80	1.58	504
*Roux. Arch. Devel. Biol.	650	1,938	242	33.5	12.5	37.2	2.55	0.97	66
*Differentiation	588	4,077	182	14.4	4.5	31.0	2.21	0.28	93
J. Neurosci.	421	17,145	—	2.5	—	—	0.13	0.05	384
Proc. Nat. Acad. Sci. USA	414	64,318	—	0.6	—	—	9.17	1.52	2,043
*Develop. Growth Differ.	409	1,668	86	24.5	5.2	21.0	1.13	0.25	79
*Teratology	407	2,540	297	16.0	11.7	73.0	2.07	0.28	80
J. Exp. Zool.	403	4,933	—	8.2	—	—	1.40	0.39	173
*Cell Differentiation	388	1,814	45	21.4	2.5	11.6	1.95	0.38	58
Cell	387	18,276	—	2.1	—	—	20.10	3.40	430
J. Comp. Neurol.	381	23,089	—	1.7	—	—	4.11	0.84	430
J. Cell Sci.	372	7,187	—	5.2	—	—	2.21	0.59	184
Exp. Cell Res.	368	10,096	—	3.6	—	—	2.48	0.67	322
*Gamete Res.	358	2,725	150	13.1	5.5	41.9	1.73	0.32	90
Int. Rev. Cytol.	332	6,700	—	5.0	—	—	4.61	1.16	38
J. Craniofac. Genet. Dev. Biol.	301	1,583	—	19.0	—	—	0.49	0.13	56
*Anat. Embryol.	296	3,415	143	8.7	4.2	48.3	1.45	0.34	91
J. Biol. Chem.	251	94,501	—	0.3	—	—	6.32	1.20	2,638
Cell Tissue Res.	243	10,677	—	2.3	—	—	1.98	0.47	338
Nature	226	35,096	—	0.6	—	—	15.25	3.26	1,165
EMBO J.	216	19,298	—	1.1	—	—	8.14	1.47	498
Develop. Brain Res.	211	7,689	—	2.7	—	—	1.98	0.41	244
Mol. Cell. Biol.	209	23,333	—	0.9	—	—	6.63	1.39	585
Amer. J. Anat.	177	3,741	—	4.7	—	—	2.11	0.39	105
J. Reprod. Fertil.	166	6,928	—	2.4	—	—	1.92	0.38	247
Teratogen. Carcin. Mut.	162	1,430	—	11.3	—	—	1.01	0.21	48
Anat. Rec.	160	4,678	—	3.4	—	—	1.45	0.46	159
Annu. Rev. Cell Biol.	153	2,634	—	5.8	—	—	14.13	1.11	18
Brain Res.	153	46,816	—	0.3	—	—	2.86	0.43	1,578
Biol. Reprod.	137	8,261	—	1.7	—	—	2.54	0.41	263
Zool. Sci.	137	2,922	—	4.7	—	—	1.01	0.31	126
Genetics	130	7,040	—	1.8	—	—	3.05	0.96	204
Scanning Electron Microsc.	116	3,909	—	3.0	—	—	0.95	0.18	122
Biochim. Biophys. Acta	112	66,751	—	0.2	—	—	2.74	0.46	2,079
Develop. Genetics	110	797	—	13.8	—	—	1.33	0.14	28
Eur. J. Cell Biol.	108	6,001	—	1.8	—	—	2.29	0.32	170
Science	108	28,600	—	0.4	—	—	12.44	3.00	803
J. Cell Physiol.	105	8,407	—	1.2	—	—	3.07	0.57	251
Acta Anat.	103	3,264	—	3.2	—	—	0.67	0.15	146
Acta Histochem.	103	3,410	—	3.0	—	—	0.88	0.21	161
Insect Biochem.	102	3,419	—	3.0	—	—	1.80	0.62	114
J. Physiol.—London	101	15,850	—	0.6	—	—	3.98	0.58	396
Prog. Histochem. Cytochem.	101	632	—	16.0	—	—	2.40	0.50	2
Bio. Cell	98	3,280	—	3.0	—	—	1.82	0.18	87
*Placenta	98	1,405	70	7.0	5.0	71.4	1.61	0.38	47
Biol. Bull.	94	3,020	—	3.1	—	—	1.74	0.37	85
Brain Res. Bull.	94	7,458	—	1.3	—	—	2.02	0.29	223

Anatomy and Embryology is the oldest journal on the list. Like *Roux's Archives*, it began publication in the nineteenth century; also like *Roux's Archives*, it and several other journals on the list changed their titles over the years. *Anatomy and Embryology* was originally known as *Archiv für Anatomie und Physiologie, Anatomische Abteilung*. Similarly, *Development* is the new name for the *Journal of Embryology and Experimental Morphology*, and *Development, Growth & Differentiation* superseded *Embryologia*. Citations to and from a journal under all its previous titles have

Table 3: Most-cited developmental biology journals. The developmental biology journals most cited by core journals in 1984-1986. Asterisks (*) indicate core journals. A=citations from core journals. B=citations from all journals. C=self-citations. D=percent of total citations that are core-journal citations (A/B). E=percent of total citations that are self-citations (self-cited rate, C/B). F=percent of core-journal citations that are self-citations (C/A). G=1986 impact factor. H=1986 immediacy index. I=1984-1986 source items.

	A	B	C	D	E	F	G	H	I
*Develop. Biol.	8,905	34,024	4,951	26.2	14.6	55.6	3.63	0.97	984
*Development	4,019	10,479	1,604	38.4	15.3	39.9	2.61	0.63	417
J. Cell Biol.	3,507	107,883	—	3.3	—	—	8.80	1.58	1,540
J. Exp. Zool.	2,414	15,043	—	16.0	—	—	1.40	0.39	615
Exp. Cell. Res.	2,130	37,411	—	5.7	—	—	2.48	0.67	1,018
*Roux. Arch. Devel. Biol.	1,591	3,938	492	40.4	12.5	30.9	2.55	0.97	187
J. Comp. Neurol.	1,452	56,037	—	2.6	—	—	4.11	0.84	1,230
*Teratology	1,231	5,598	1,133	22.0	20.2	92.0	2.07	0.28	260
Cell Tissue Res.	979	30,111	—	3.3	—	—	1.98	0.47	1,051
*Differentiation	960	4,491	345	21.4	7.7	35.9	2.21	0.28	273
J. Reprod. Fertil.	894	20,365	—	4.4	—	—	1.92	0.38	718
Biol. Reprod.	844	19,528	—	4.3	—	—	2.54	0.41	796
Anat. Rec.	798	16,898	—	4.7	—	—	1.76	0.46	496
J. Cell Sci.	783	11,957	—	6.5	—	—	2.21	0.59	548
*Develop. Growth Differ.	782	2,318	278	33.7	12.0	35.5	1.13	0.25	215
Amer. J. Anat.	744	12,246	—	6.1	—	—	2.11	0.39	279
J. Morphol.	693	7,239	—	9.6	—	—	0.88	0.26	290
*Anat. Embryol.	614	4,668	406	13.2	8.7	66.1	1.45	0.34	279
*Cell Differentiation	504	2,054	109	24.5	5.3	21.6	1.95	0.38	184
J. Neurosci. Res.	502	18,382	—	2.7	—	—	22.62	3.66	274
*Gamete Res.	481	1,885	326	25.5	17.3	67.8	1.73	0.32	233
J. Ultrastruct. Molec. Struct. Re.	480	13,905	—	3.5	—	—	1.42	0.35	212
Genetics	449	22,870	—	2.0	—	—	3.05	0.96	517
Amer. Zool.	394	8,421	—	4.7	—	—	2.53	0.61	229
J. Anat.	377	10,893	—	3.5	—	—	1.04	0.39	330
Int. Rev. Cytol.	366	9,253	—	4.0	—	—	4.61	1.16	122
Biol. Bull.	331	9,144	—	3.6	—	—	1.74	0.37	287
*Placenta	229	1,187	192	19.3	16.2	83.8	1.61	0.38	156

been included in the information under that journal's current title.

Both *Anatomy and Embryology* and *Roux's Archives* are published in the Federal Republic of Germany, as is the much newer journal *Differentiation*. US publishers also account for three journals on the list: *Developmental Biology, Teratology*, and *Gamete Research*. Two journals—*Development* and *Placenta*—are published in the UK. One each is published in Ireland and Japan: *Cell Differentiation* is published in Limerick, while *Development, Growth & Differentiation* is published in Tokyo. All the journals in Table 1 publish articles in English, but *Anatomy and Embryology* and *Development, Growth & Differentiation* also include articles in German and in French.

The Journals That Most Often Cited the Core

We will consider the 10 core journals a single journal, constituting a "macrojournal of developmental biology," if you will. Using this macrojournal, we identified and ranked both the journals that cite it as well as those that are cited by it. At ISI® we have a computer program that facilitates this process on a mainframe. We hope to develop it for a personal computer in the future.

Tables 2 and 3 show citation information for the journals that, respectively, cite and are cited by the core developmental biology journals. The 10 core developmental biology journals published slightly over 1,100 articles in 1986, representing 0.18 percent of the 625,400 items covered in the 1986 *SCI*. These articles contained 37,078 references in 1986, about 0.37 percent of the approximately 10 million references processed that year to create the *SCI*. Thus, the average developmental biology article in 1986 cited approximately 33 references, as compared with the average of 16 for all the other *SCI* items. The latter, however, includes short items like letters and editorials.

Table 4: Core-journal impact factors. The 1986 impact factors of core journals using different two-year bases. Journals are listed in alphabetic order. A=1984-1985. B=1983-1984. C=1982-1983. D=1981-1982. E=1980-1981.

	A	B	C	D	E
Anat. Embryol.	1.45	1.91	1.68	1.44	1.53
Cell Differentiation	1.95	2.01	1.71	1.23	1.15
Development	2.61	3.37	2.87	2.40	2.05
Develop. Biol.	3.63	4.30	4.15	3.73	3.57
Develop. Growth Differ.	1.13	1.23	1.31	1.22	1.05
Differentiation	2.21	2.58	2.62	2.96	2.78
Gamete Res.	1.73	1.93	1.74	1.90	1.77
Placenta	1.61	1.95	1.88	2.65	2.85
Roux. Arch. Devel. Biol.	2.55	2.29	1.65	1.57	1.49
Teratology	2.07	1.77	1.89	2.06	1.91

The journals in Table 2 are ranked by the number of their citations to the core in 1986; the threshold for inclusion was 94 or more citations. The 10 core journals appear on the list and are denoted by asterisks. The 49 journals in Table 2 accounted for 15,600 of the 26,200 citations to the core, or 59.7 percent of all the citations the 10 core journals received in 1986. The 39 noncore journals on the list gave out approximately 617,000 citations, of which 8,200 (or 1.3 percent) were to the developmental biology core. By contrast, of the core journals' 37,000 citations, 7,400 (about 20 percent) were to the core. The core journal that has the highest percentage of citations to other core journals is *Roux's Archives*: 33.5 percent of its citations were to core journals. *Development* was a close second at 28.8 percent. The noncore journal that had the highest percentage of citations to the core is the *Journal of Craniofacial Genetics and Developmental Biology*, at 19 percent.

The Journals Most Often Cited by the Core

To identify the journals most frequently cited by the core developmental biology journals, we used three years of data, from 1984 through 1986. We also used a "double threshold," based on the number of citations from the core and the percentage of core citations to total citations. Table 3 lists the 28 journals most frequently cited by the core. These journals had to have at least 220 citations from the core. In addition, in order to filter out the large, multidisciplinary journals such as *Science*, *Nature*, and *Cell* that would otherwise have appeared on the table, at least 2 percent of each journal's citations had to be from the core.

The journals in Table 3 received 37,500 citations from the core journals from 1984 to 1986, accounting for 37.7 percent of the 99,300 citations given out by the core journals during that span. About 27.3 percent (19,300) of the core journals' total of 70,600 citations came from other core journals. The noncore journal with the highest percentage of cites from the core is the *Journal of Experimental Zoology*: 16 percent of its citations came from core journals in the period 1984-1986. The core journal with the highest percentage of core citations is *Roux's Archives*, at 40.4 percent. In terms of absolute number of citations from the core, the most-cited core journal is *Developmental Biology*.

Impact

A journal's impact factor gives an indication of how much the material it publishes is used. Each journal's 1986 impact factor was calculated by dividing the number of 1986 citations to the journal's 1984 and 1985 articles by the number of articles it published in those two years. The 1986 impact factor for the field of developmental biology as a whole was about 2.1, meaning that 1984 and 1985 articles received, on average, two citations from 1986 articles.

It should be mentioned that impact factors are partly dependent on the base years used to calculate them. For instance, we can also derive a 1986 impact factor by using a journal's 1986 citations to articles pub-

Table 5: Half-lives. The 1986 *SCI®* cit*ed* and cit*ing* half-lives of core developmental biology journals. Journals are listed in alphabetic order. A = cit*ed* half-life. B = cit*ing* half-life.

	A	B
Anat. Embryol.	5.1	7.8
Cell Differentiation	3.7	6.6
Development	6.9	6.5
Develop. Biol.	5.7	6.2
Develop. Growth Differ.	5.8	6.7
Differentiation	4.7	5.1
Gamete Res.	4.0	6.7
Placenta	3.8	6.9
Roux. Arch. Devel. Biol.	7.8	7.8
Teratology	6.7	7.7

lished in, say, 1981 and 1982; this usually results in a slightly different impact factor. In Table 4, we provide the 1986 impact factors for all 10 core journals using five different two-year bases. The table shows that, for developmental biology, the highest value is obtained when the 1983-1984 period is used as a base.

Half-Life Data

"Half-life" refers to the median ages of a journal's cit*ed* and cit*ing* literature and indicates the speed with which a field moves. Table 5 lists the cited and citing half-lives for the 10 developmental biology core journals. The cited half-lives shown are the median ages of the articles from each core journal that were cited in 1986. *Cell Differentiation* is the core developmental biology journal with the shortest cited half-life, at 3.7 years; with a figure of 7.8, *Roux's Archives* has the longest cited half-life.

The average is 5.4 years, meaning that, on average, half of the 1986 citations to core developmental biology journals were to articles they published over the past 5.5 years or so. Since the average cited half-life for all journals covered in the 1986 *SCI* is 6.8 years, this figure indicates that developmental biology literature obsolesces somewhat faster than average. The average age of the articles cited in developmental biology journals is somewhat higher than that for other fields in the life sciences; for example, the cited half-life for immunology is 4.3 years. However, the average cited half-life for developmental biology is identical to that for molecular biology (5.4) and shorter than that for astronomy (6.1).

Cit*ing* half-life is the median age of the literature cited *by* a journal, giving an indication of the age of the literature that each journal cites. In 1986 the average citing half-life of developmental biology core journals was 6.8 years, which matches the average for all 1986 journals covered in the *SCI*. *Differentiation* has the shortest citing half-life,

Table 6: The 1986 *SCI®/SSCI®* research fronts that include at least 25 citing documents published in core developmental biology journals. A = number of developmental biology core articles citing the core of each front. B = total number of citing documents. C = total number of core documents.

Number	Name	A	B	C
86-6423	Antigen recognition, general immunological detection, and mammalian skeletal muscles	125	8,512	3
86-0259	Putative fibronectin receptor complex, laminin synthesis, PC12 cells, and type-IV collagen	88	1,155	56
86-3239	Preimplantation of mouse embryos, starfish oocyte maturation, and oocytes of the Prosobranch mollusk *Patella vulgata*	62	241	20
86-1382	Hemagglutinin neuraminidase gene of Newcastle-disease virus, nucleotide-sequence analysis, transcription of genes, and cDNA clones	59	7,995	36
86-4325	*Xenopus laevis* embryos, *Xenopus* eggs, early *Drosophila* development, mitotic PTK1 cells, gene activity, histone gene-expression, and multipolar spindles	55	135	7
86-0403	*Drosophila* embryos, mouse homeo box gene, spatial expression of homeotic genes, and bithorax complex	47	357	20
86-3428	Intracellular pattern reversal, mechanical models for biological pattern formation, positional systems, cell patterning, and early development	44	147	10
86-2889	Early mouse embryos, two-dimensional electrophoresis, heat-shock protein synthesis, and *in vivo* biosynthesis	34	817	2
86-0338	Intermediate filament proteins, cytokeratin expression, human epidermal keratin filaments, epithelial keratins, and myoepithelial basal cells	29	829	59
86-4823	Cell surface cAMP receptors of *Dictyostelium discoideum*, developmental regulation, prespore cells, and pre-stalk gene-expression in dictyostelium	26	132	10

Table 7: The most-cited articles from each core developmental biology journal according to the 1955-1986 *SCI®*. Articles are listed in alphabetic order by first author. A=1955-1986 citations. The number of 1986 citations appears in parentheses. B=total number of papers from that journal cited at least 50 times. An asterisk (*) indicates that the paper was the subject of a *Citation Classic®* commentary. The issue, year, and edition of *Current Contents®* in which the commentary appeared follow the bibliographic reference. *SCI* research-front numbers for 1986 also follow the reference.

A		Bibliographic Data	B
120	(0)	**Birnie G D, MacPhail E, Young B D, Getz M J & Paul J.** The diversity of the messenger RNA population in growing Friend cells. *Cell Differentiation* 3:221-32, 1974.	16
51	(17)	**Brown P J & Johnson P M.** Isolation of a transferrin receptor structure from sodium deoxycholate-solubilized human placental syncytiotrophoblast plasma membrane. *Placenta* 2:1-10, 1981.	1
188	(11)	**Chernoff G F.** The fetal alcohol syndrome in mice: an animal model. *Teratology* 15:223-9, 1977.	43
253	(9)	**Curry J L & Trentin J J.** Hemopoietic spleen colony studies. I. Growth and differentiation. *Develop. Biol.* 15:395-413, 1967.	627
468	(26)	**Enesco M & Leblond C P.** Increase in cell number as a factor in the growth of the organs and tissues of the young male rat. *J. Embryol. Exp. Morphol.* 10:530-62, 1962. (Superseded title of *Development*) 86-5249	174
282	(13)	**Fischbach G D.** Synapse formation between dissociated nerve and muscle cells in low density cell cultures. *Develop. Biol.* 28:407-29, 1972.	627
227	(56)	**Heby O.** Role of polyamines in the control of cell proliferation and differentiation. *Differentiation* 19:1-20, 1981. 86-1445	33
91	(0)	**Karasaki S.** Electron microscopic studies on cytoplasmic structures of ectoderm cells of the *Triturus* embryo during the early phase of differentiation. *Embryologia* 4:247-72, 1959. (Superseded title of *Develop. Growth Differ.*)	13
326	(1)	**Markert C L & Ursprung H.** The ontogeny of isozyme patterns of lactate dehydrogenase in the mouse. *Develop. Biol.* 5:363-81, 1962.	627
311	(15)	* **New D A T.** A new technique for the cultivation of the chick embryo *in vitro*. *J. Embryol. Exp. Morphol.* 3:326-31, 1955. (Superseded title of *Development*) (40/87/LS; AB&ES)	174
270	(26)	**Olson L & Seiger A.** Early prenatal ontogeny of central monoamine neurons in the rat: fluorescence histochemical observations. *Z. Anat. Entwicklungsgesch.* 137:301-16, 1972. (Superseded title of *Anat. Embryol.*)	46
104	(14)	**Schuel H.** Secretory functions of egg cortical granules in fertilization and development: a critical review. *Gamete Res.* 1:299-382, 1978.	4
289	(14)	**Shainberg A, Yagil G & Yaffe D.** Alterations of enzymatic activities during muscle differentiation *in vitro*. *Develop. Biol.* 25:1-29, 1971.	627
177	(16)	**Steiner E.** Establishment of compartments in the developing leg imaginal discs of *Drosophila melanogaster*. *Roux. Arch. Devel. Biol.* 180:9-30, 1976.	43
295	(9)	**Stevens L C.** The development of transplantable teratocarcinomas from intratesticular grafts of pre- and postimplantation mouse embryos. *Develop. Biol.* 21:364-82, 1970.	627
313	(3)	**Trelstad R L, Hay E D & Revel J-P.** Cell contact during early morphogenesis in the chick embryo. *Develop. Biol.* 16:78-106, 1967.	627
449	(26)	* **Winick M & Noble A.** Quantitative changes in DNA, RNA, and protein during prenatal and postnatal growth in the rat. *Develop. Biol.* 12:451-66, 1965. (23/87/LS) 86-5249	627

at 5.1 years, while *Anatomy and Embryology* and *Roux's Archives* have the longest, at 7.8 years.

Immediacy

An indication of how quickly the material in a field is used is the immediacy index, a measure of how often a journal's articles are cited in the same year in which they were published. The immediacy index for each journal is given in column H in Tables 2 and 3. The average 1986 immediacy index for the entire *SCI* is 1.35, which means that, on average, each article in the 1986 *SCI* averaged a little more than 1 citation from other 1986 articles; the average 1986 immediacy index for developmental biology journals is 0.48. In 1986 *Developmental Biology* and *Roux's Archives* ranked first among the core journals, with immediacy indexes of 0.97 each. *Development* was next with an immediacy index of 0.63.

Research Fronts

To get an idea of the research topics addressed in developmental biology, we com-

Table 8: Highly cited articles published in noncore journals cited at least 13 times by core developmental biology journals in the 1986 *SCI*®. Articles are listed in alphabetic order by first author. Articles appearing in the 1,000 most-cited papers indexed in the the 1961-1982 *SCI* have been excluded. A = 1986 citations from core journals. B = total 1955-1986 *SCI* citations. An asterisk (*) indicates that the paper was the subject of a *Citation Classic*® commentary. The issue, year, and edition of *Current Contents*® in which the commentary appeared follow the bibliographic reference. *SCI* research-front numbers for 1986 also follow the reference.

A	B	Bibliographic Data
14	471	**Dumont J N.** Oogenesis in *Xenopus laevis* (Daudin). *J. Morphol.* 136:153-80, 1972.
14	297	**Edelman G M.** Cell adhesion molecules. *Science* 219:450-7, 1983. 86-5114
13	60	**Gerhart J, Ubbels G, Black S, Hara K & Kirschner M.** A reinvestigation of the role of the grey crescent in axis formation in *Xenopus laevis*. *Nature* 292:511-6, 1981.
15	226	**Gooi H C, Feizi T, Kapadia A, Knowles B B, Solter D & Evans M J.** Stage-specific embryonic antigen involves $\alpha 1 \rightarrow 3$ fucosylated type 2 blood group chains. *Nature* 292:156-8, 1981. 86-6038
17	215	**Martin G R.** Teratocarcinomas and mammalian embryogenesis. *Science* 209:768-76, 1980. 86-7641
21	221	**Masui Y & Clarke H J.** Oocyte maturation. *Int. Rev. Cytol.* 57:185-282, 1979. 86-3239
13	87	**Mehdy M C, Ratner D & Firtel R A.** Induction and modulation of cell-type-specific gene expression in dictyostelium. *Cell* 32:763-71, 1983. 86-4823
13	1,760	**Mesulam M-M.** Tetramethyl benzidine for horseradish peroxidase neurohistochemistry: a non-carcinogenic blue reaction-product with superior sensitivity for visualizing neural afferents and efferents. *J. Histochem. Cytochem.* 26:106-17, 1978.
13	159	**Newgreen D & Thiery J-P.** Fibronectin in early avian embryos: synthesis and distribution along the migration pathways of neural crest cells. *Cell Tissue Res.* 211:269-91, 1980.
16	130	**Newport J & Kirschner M.** A major developmental transition in early Xenopus embryos: I. Characterization and timing of cellular changes at the midblastula stage. *Cell* 30:675-86, 1982. 86-4325
13	1,465	**O'Farrell P Z, Goodman H M & O'Farrell P H.** High resolution two-dimensional electrophoresis of basic as well as acidic proteins. *Cell* 12:1133-42, 1977.
22	337	**Solter D & Knowles B B.** Monoclonal antibody defining a stage-specific mouse embryonic antigen (SSEA-1). *Proc. Nat. Acad. Sci. USA* 75:5565-9, 1978. 86-6038
21	3,167	**Thomas P S.** Hybridization of denatured RNA and small DNA fragments transferred to nitrocellulose. *Proc. Nat. Acad. Sci. USA* 77:5201-5, 1980. 86-1382
35	5,836	**Towbin H, Staehelin T & Gordon J.** Electrophoretic transfer of proteins from polyacrylamide gels to nitrocellulose sheets: procedure and some applications. *Proc. Nat. Acad. Sci. USA* 76:4350-4, 1979. 86-6423
20	289	**Whittingham D G.** Culture of mouse ova. *J. Reprod. Fertil.* 14(Supp.):7-21, 1971. 86-3239
15	584	* **Wolpert L.** Positional information and the spatial pattern of cellular differentiation. *J. Theor. Biol.* 25:1-47, 1969. (3/86/LS) 86-3428

piled lists of highly cited articles from both core and noncore developmental biology journals, as well as an inventory of 1986 research fronts that include at least 25 articles published in core developmental biology journals among their citing documents. The latter are shown in Table 6.

It should be noted that, on the basis of their titles alone, the connection between developmental biology and these research fronts may not be immediately apparent in all cases. An example is the research front with the greatest number of citing papers from developmental biology journals. This front, entitled "Antigen recognition, general immunological detection, and mammalian skeletal muscles" (#86-6423), like several others in Table 6, focuses on methods papers that are broadly applicable in a number of fields—including developmental biology. Of the 8,500 articles published in 1986 that constitute this front, only 125 were published in core developmental biology journals. The relevance of the subject matter of this front to developmental biology might not be evident to someone keeping up with the field by browsing through a dozen core journals.

Classic Papers

Table 7 lists the most-cited articles from each of the developmental biology core journals for the period 1955-1986. The most-cited paper on the list was published in *Development* in 1962 by M. Enesco and C.P. Leblond when they were at the Department of Anatomy, McGill University, Montreal, Canada. Cited about 470 times (26 times in

1986 alone), their paper discusses cell enlargement and proliferation in relation to the growth of organs and tissues. It also helped inspire another paper that appears in Table 7, a classic by Myron Winick and Adele Noble, Department of Pediatrics, Cornell University Medical College, New York. Cited about 450 times, it is also the most-cited paper published in *Developmental Biology*.

Winick and Noble's paper used quantitative changes in prenatal and postnatal DNA, RNA, and protein in rats to chart the cellular growth of various organs from before birth to adulthood. They found that growth could be divided into three distinct phases: a period of increase in cell number (hyperplasia); a period of increase in both cell number and cell size (hypertrophy); and a period in which cell size alone increased. The *Developmental Biology* paper both confirmed and extended the work of Enesco and Leblond, and in his recent *Citation Classic*® commentary on this work, Winick also credited it with providing the foundation for later studies of growth in children.[16] Interestingly, this paper also led Winick and Noble to experiment with the effects of malnutrition occurring during one or another of these growth periods[17]—a paper that itself is a classic and appears in our upcoming study of nutrition journals.

Table 8 lists the most-cited developmental biology articles that were published in noncore journals. We selected these articles by processing all the references cited in the 1986 editions of the 10 core journals. We then created a "mini-citation index" of the papers cited and ranked these papers by their frequency.

The papers in Table 8 have each been cited at least 13 times by the core journals. *Cell*, *Nature*, *Science*, and the *Proceedings of the National Academy of Sciences of the USA* are well represented on this list. It should be noted, however, that this necessarily limited list omits numerous older, highly cited papers that did not meet the threshold for inclusion. For instance, Hamburger's most-cited paper,[8] on the stages in the development of chick embryos, appeared on a list of 100 highly cited papers.[18] But it has not received enough citations from the relatively new journals that make up the core of this field to meet the criteria for Table 8.

Gerald M. Edelman, Rockefeller University, New York, the winner of the 1972 Nobel Prize in physiology or medicine, has a paper on cell adhesion in Table 8. Wolpert wrote a paper describing patterns of cell differentiation in 1969; he authored a *Citation Classic* commentary on the paper in 1986.[19]

In it he writes that he was intrigued by what he called

> the French Flag Problem: how a line of similar cells could form a pattern such that one-third was blue, one-third white, and one-third red. I was collaborating with two theoreticians, Mary Williams and Michael Apter. Apter was keen on the obvious solution—number the cells from each end, and the cells can thus compute which third of the line they are in! For some time, I resisted this solution as being too complex but suddenly realized that, in more general terms, if cells knew their position, then a larger number of pattern problems could be accounted for.... The paper has been frequently cited because, I hope, it both defined the general field of pattern formation and provided a particular conceptual framework.[19]

Conclusion

Comparing the data from Tables 2 and 3, we find that not only do all 10 core journals appear on both but that the same 2 core journals are at the top of each list—*Developmental Biology* and *Development*. These two journals thus rank highest both in terms of their citations to the core developmental biology journals and their citations from the core.

Perhaps not surprisingly, these two journals also rank first and second in terms of the number of source items they published (346 for *Developmental Biology* and 161 for *Development*) and in terms of impact (3.63 for *Developmental Biology* and 2.61 for *Development*). As mentioned earlier, *Developmental Biology* and *Roux's Archives* rank first in immediacy, with *Development* third, at 0.63.

Clearly, these two journals, along with *Roux's Archives*, are quite influential in the field of developmental biology. But perhaps more than in other specialties, developmental biologists also rely on large, multidisciplinary journals, such as *Cell*, *Science*, and *Nature*, and other broad journals too numerous to mention. The most telling indication of this is in Table 6, where the research fronts, cutting across artificial journal boundaries, show how large the ancillary literature really is. Over 20,000 papers were published on these research-front topics in 1986. It is not surprising that so many readers of *Current Contents®* find it necessary to scan the contents pages of a diversified group of journals each week. It would have been interesting to create a detailed map of the field of developmental biology using some of the techniques we have described elsewhere,[20] but such *ad hoc* clustering involves more computer time than we can justify for an essay. That's an exercise for future consideration. However, since we are frequently asked about this possibility we would be glad to discuss such projects with anyone interested. Please contact Dr. Henry Small, ISI's director of corporate research, at (215) 386-0100, extension 1307.

* * * * *

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