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Meaningful metrics

‘Scientific Breakthroughs’ produced in South Africa

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Universiteit Leiden

Outline

- Research question
- Identifying breakthroughs
- South Africa's scientific breakthroughs
- Concluding remarks

Research question

What are key characteristics of scientific 'breakthroughs' South Africa produced in the period 1996-2015?

- *Development over time*
- *Universities*
- *Fields of science*
- *Organizational collaboration*

What is needed to answer the research question?

1. Clearly specified analytical methods to identify (potential) breakthroughs
2. A large scale of data source(s) with relevant information
   - Web of Science (SCOPUS is also suitable)
   - Patent database (PATSTAT)
   - Focus is on ‘articles’ and ‘letters’

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Algorithm based methods

We developed a series of algorithms for early-stage identification of potential breakthrough discoveries

This analytical approach focuses on individual publications

The empirical findings relate to aggregate publication sets

Foreseeing tipping points

Based on:

- Scheffer, M. (2009). *Critical Transitions in Nature and Society. Princeton Studies in Complexity*. Princeton University Press, Princeton, NJ, USA.
- Scheffer, M. (2010). Complex systems: Foreseeing tipping points. *Nature,* 467(7314):411– 412.
- Scheffer, M., Bascompte, J., Brock, W. A., Brovkin, V., Carpenter, S. R., Dakos, V., Held, H., van Nes, E. H., Rietkerk, M., and Sugihara, G. (2009). Early-warning signals for critical transitions. *Nature*, 461(7260):53–59.

What is a breakthrough?

There is no general agreed upon definition of ‘breakthrough’ that can be operationalized

- Breakthrough is an ambiguous concept
- It is not immediately clear if a scientific discovery is a breakthrough or not
- But time will tell

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When is the change irreversible?

Merwedebrug, 2016

OR

Tacoma bridge, 1940

Breakthrough detection algorithms

Discovery characteristics used in the breakthrough algorithms:

- Number of researchers attracted (RII)
- Shift from discovery oriented research to applied research (ARI)
- Crossing disciplinary borders (CDI)
- Research team discoveries (DII)
- Small scale citation clustering (RNI)

Observations in short time windows (36 months from publication)

Some validation results (papers published in1990 -1994)

- Nature's *The top 100 papers*[*] contains 13 publications published in 1990-1994
  - 2 publications are not included in this study, 'wrong' document type
  - 11 remaining publications were recognised

- For 5 of the 8 Nobel Prizes in Chemistry, Physics, and Physiology or Medicine for which scholarly work from 1990-1994 forms the scientific basis at least one of the seminal publications was identified

* van Noorden, R., Maher, B., and Nuzzo, R. (2014). The top 100 papers - nature explores the most-cited research of all time. *Nature*, 514(7524):550–553.

Does the approach work?

(small sample consisting of 60 breakthrough papers)

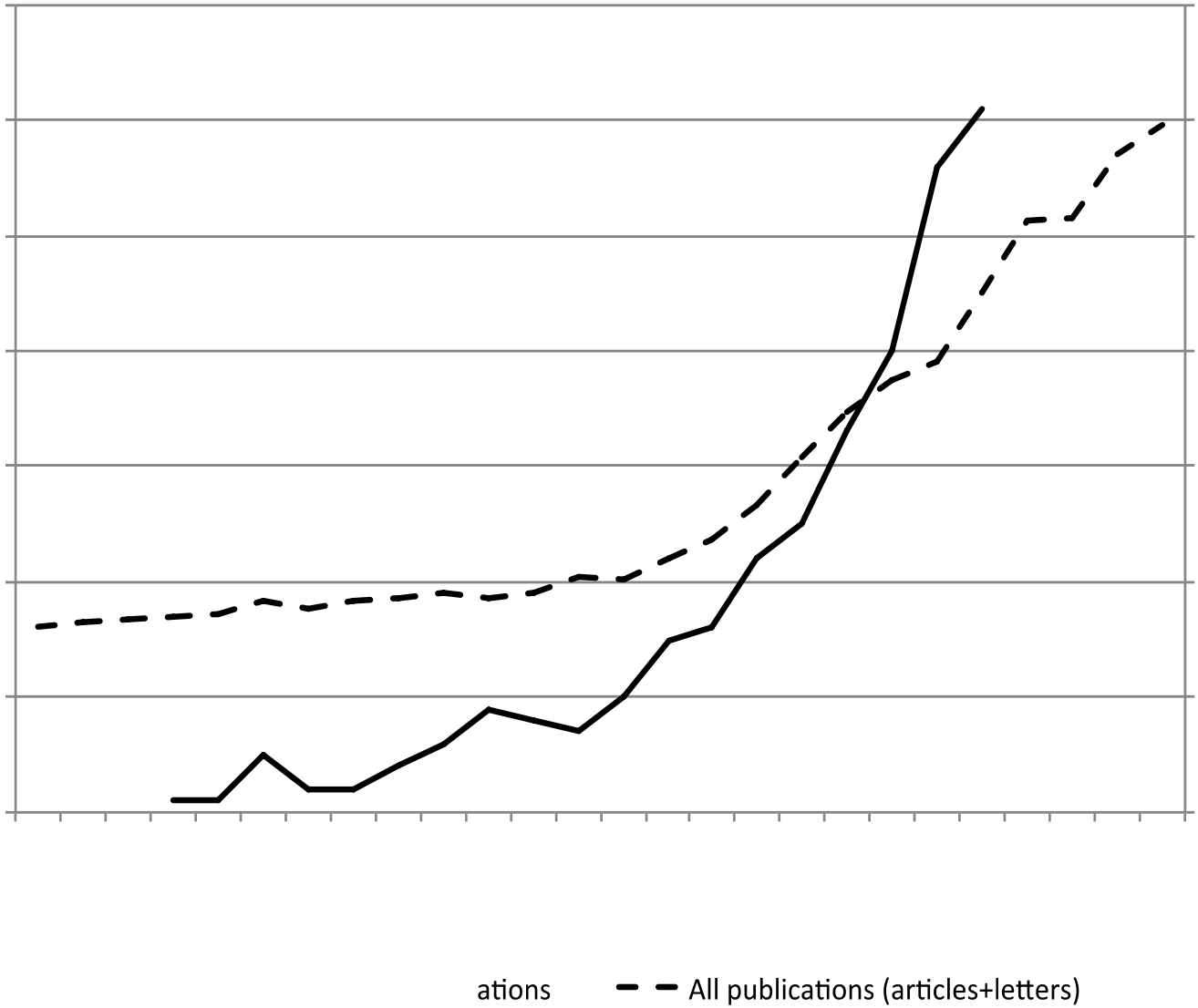
Algorithm	Publications identified as potential breakthrough	*In Nature's* Top-100 most cited list	Cited in patents	Times cited by review publications
RII	15	0	7	18 – 150
ARI	26	8	20	48 – 2133
CDI	33	10	25	48 – 2133
DII	12	0	6	1 – 684
RNI	16	0	2	1 – 38

Articles, letters from 1990-1994

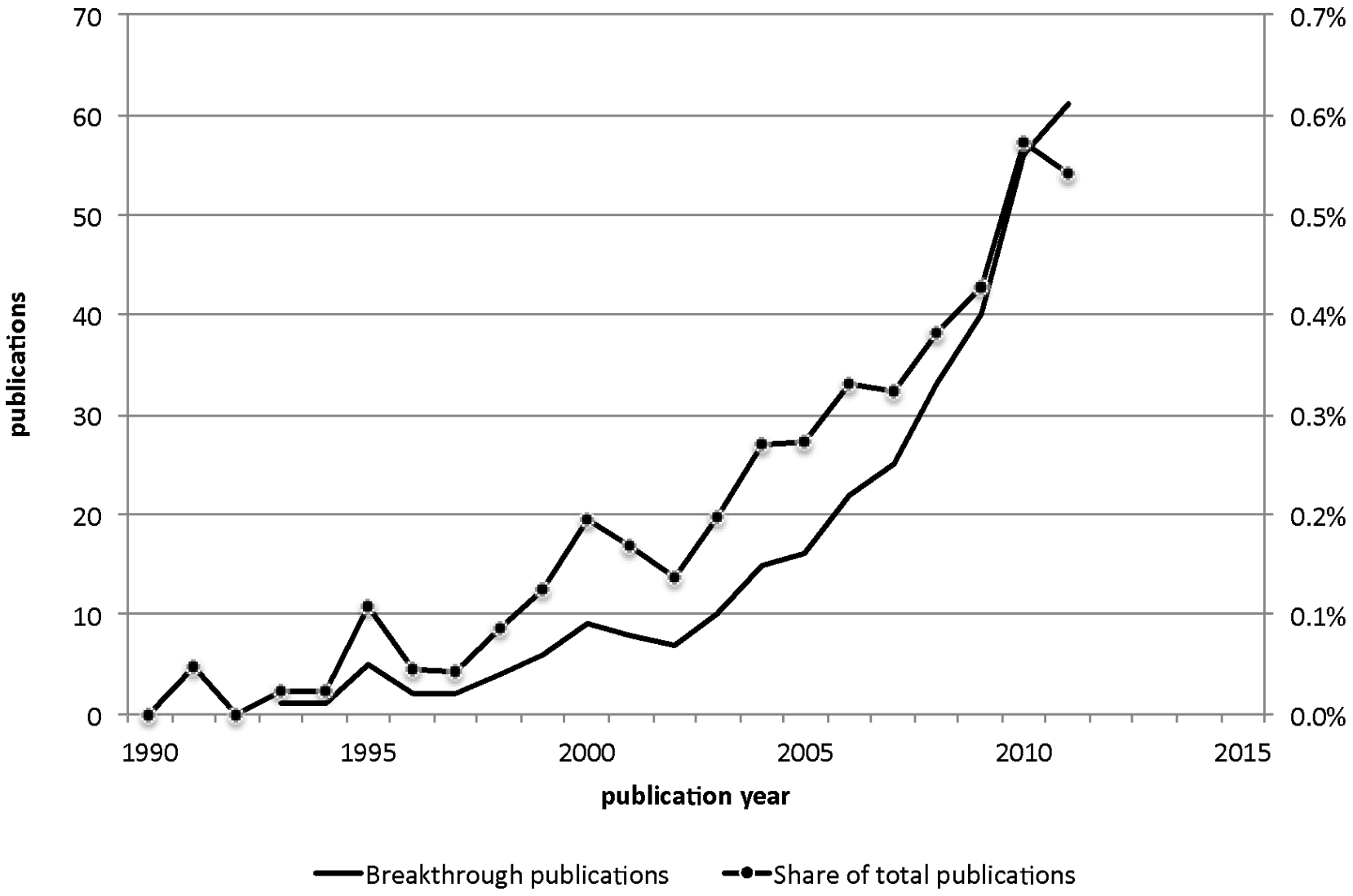
Publications

- Winnink, J. J. and Tijssen, R. J. W. (2014). R&D dynamics and scientific breakthroughs in HIV/AIDS drugs development: the case of integrase inhibitors. *Scientometrics,* 101(1):1- 16.
- Winnink, J. J. and Tijssen, R. J. W. (2015). Early stage identification of breakthroughs at the interface of science and technology: lessons drawn from a landmark publication. *Scientometrics*, 102(1):113-134.
- Winnink, J. J., Tijssen, R. J. W., and van Raan, A. F. J. (2013). The discovery of 'introns'; an analysis of the science-technology interface. In Hinze, S. and Lottman, A., editors, *Trans- lational twists and turns: science as a socio-economic endeavor - Proceedings of STI 2013 Berlin (18th International Conference on Science and Innovation Indicators*, pages 427-438.
- Winnink, J. J., Tijssen, R. J. W., and van Raan, A. F. J. (2015). Theory-changing breakthroughs in science: the impact of research teamwork on scientific discoveries. *Journal of the Association for Information Science and Technology (JASIST),* on-line first (21 Mar 2015):1-14.
- Winnink, J. J., Tijssen, R. J. W., and van Raan, A. F. J. (2016). Can early-detection algorithms of breakout papers uncover scientific breakthroughs? (to be published in *PLoS One*)

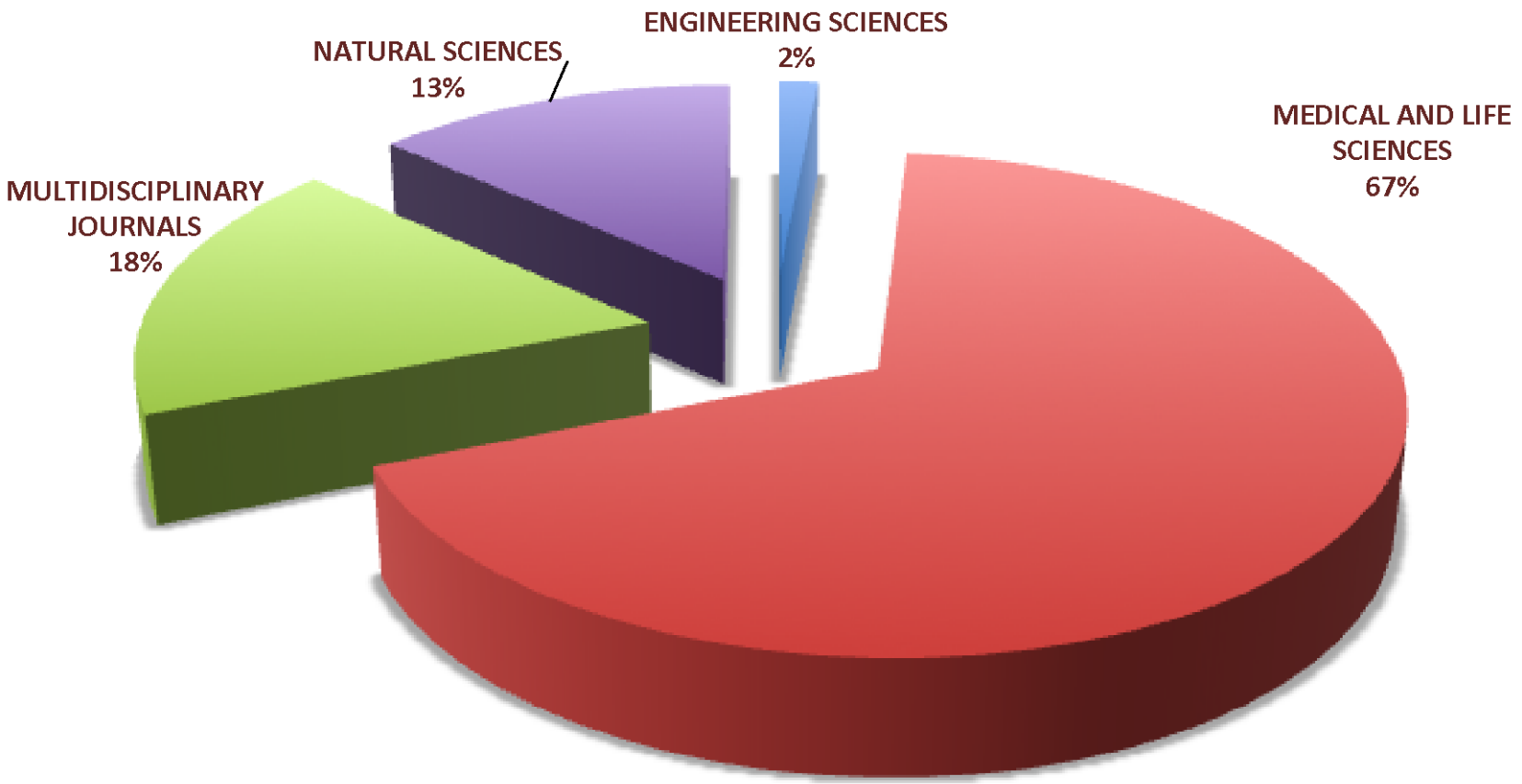
Output trends in South African science: total output and breakthrough output



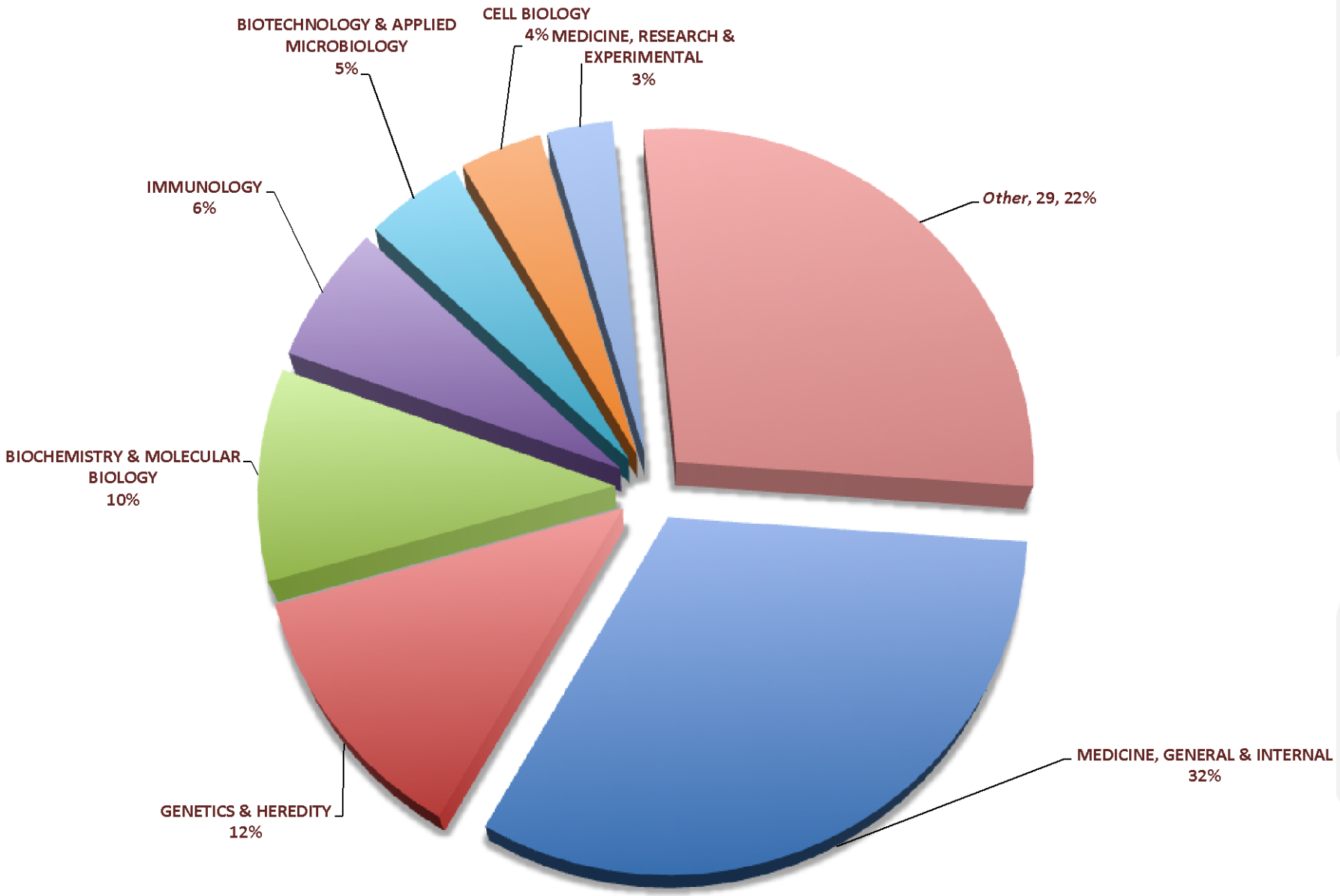
Output trends in South African science: breakthrough output and share



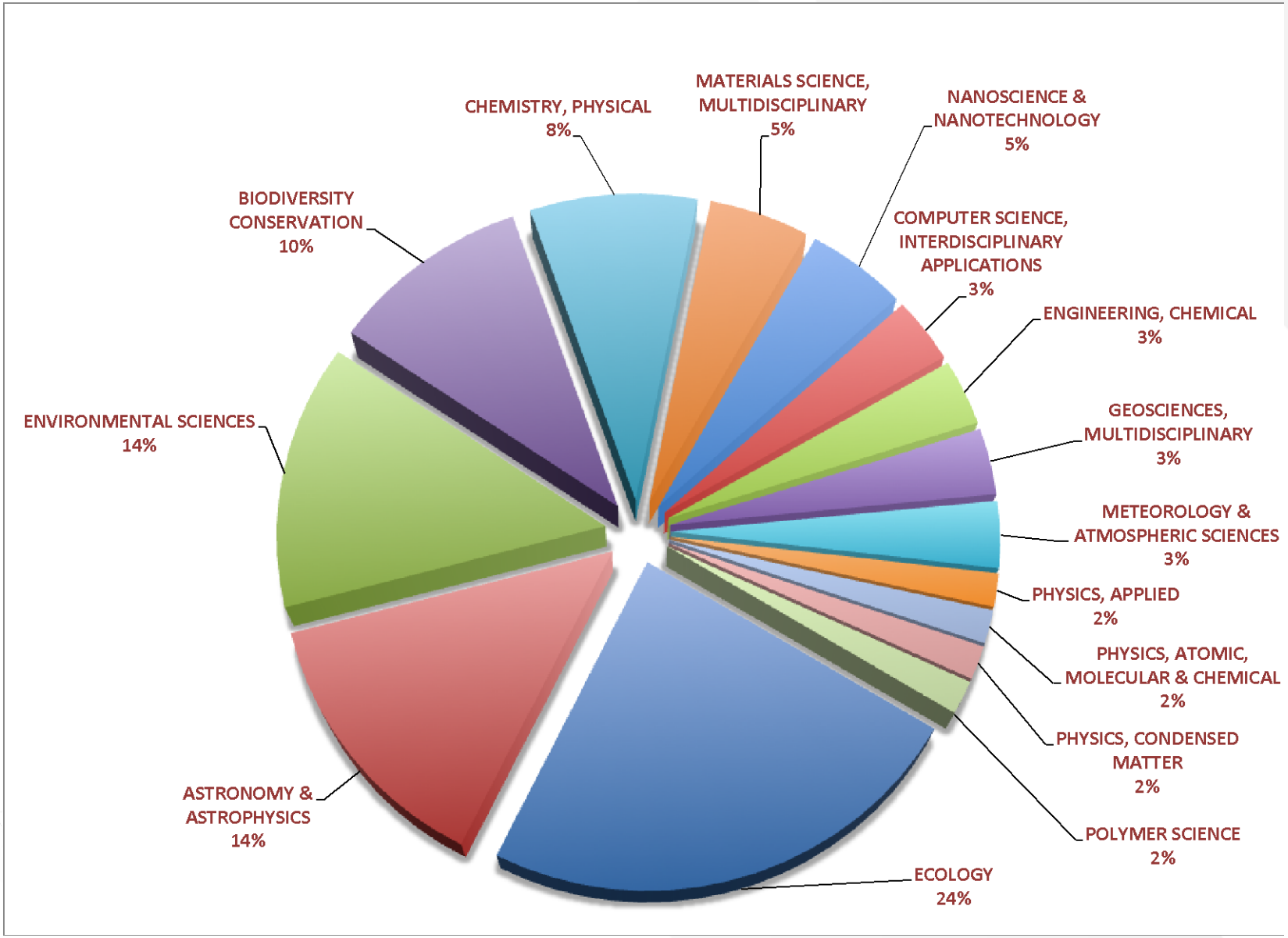
Breakthrough publications across science fields (1996-2015)



Medical and Life sciences - breakthrough publications (1996-2015)



Natural sciences - breakthrough publications (1996-2015)



Empirical results: comparing South African universities

Selection criterion: large and medium-sized research-active universities

Indicators:

1. Breakthrough output
2. Top 1% highly cited papers output
3. Cited in top 10% most-cited patents output

Breakdown by research collaboration type

Highly cited publications

- Publications from 1996-2012 belonging to top 1% most cited
  - Publication year
  - Science field (35)
  - Citation window: 36 months after publication date

Publications cited in patents

Patents cite two types of publications:

1. Other patents
2. Non patent publications:
   - Scientific publications
   - Other information (international standards, handbooks, YouTube videos, …)

Technical specifications

- Cited publications from 1996-2012
- Science field
- Citation window: 36 months after publication date

Breakthrough publication output: distribution across universities

	SA single institute	SA domestic	SA + African continent	SA + Rest of the World	Total
University of Cape Town	1	1	0	29	31
Stellenbosch University	0	0	0	15	15
University of the Witwatersrand	0	1	0	10	11
University of Pretoria	2	1	0	6	9
University of KwaZulu-Natal	0	0	0	8	8
North West University	0	1	0	3	4
University of the Western Cape	0	0	0	4	4
University of Johannesburg	1	1	0	1	3
Nelson Mandela Metropolitan University	0	0	0	2	2
Rhodes University	1	0	0	1	2
Durban University of Technology	1	0	0	0	1

Top 1% publication output: distribution across universities

	SA single institute	SA domestic	SA + African continent	SA + Rest of the World	Total
University of Cape Town	54	22	2	307	385
University of the Witwatersrand	38	18	1	180	237
Stellenbosch University	31	6	1	160	198
University of KwaZulu-Natal	24	15	1	135	175
University of Pretoria	25	7	1	88	121
University of Johannesburg	11	2		49	62
North West University	3	2	1	52	58
University of the Western Cape	6	2		38	46
Rhodes University	13	4		21	38
University of the Free State	3	3		31	37

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University of the Western Cape	6	2		38	46
Rhodes University	13	4		21	38
University of the Free State	3	3		31	37
University of South Africa	3	2		11	16
Nelson Mandela Metropolitan University	1	3		9	13
Durban University of Technology	6			4	10
Tshwane University of Technology	1	6		2	9
Cape Peninsula University of Technology	2	1		5	8
University of Venda				3	3

Cited in top 10% most-cited patents output: distribution across universities

	SA single institute	SA domestic	SA + African continent	SA + Rest of the World	Total
University of Cape Town	72	50	0	299	421
Stellenbosch University	83	49	0	149	281
University of the Witwatersrand	64	46	0	131	241
University of Pretoria	54	36	3	91	184
University of KwaZulu-Natal	39	29	1	93	162
University of the Free State	18	22	0	31	71
North West University	16	15	0	29	60
University of the Western Cape	13	10	0	22	45
Rhodes University	23	8	0	10	41
University of Johannesburg	20	6	0	13	39
Nelson Mandela Metropolitan University	11	12	1	7	31

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University of Johannesburg	20	6	0	13	39
Nelson Mandela Metropolitan University	11	12	1	7	31
Tshwane University of Technology	4	6	2	10	22
Cape Peninsula University of Technology	0	7	0	4	11
Durban University of Technology	3	3	0	3	9
University of South Africa	2	2	1	2	7
University of Venda	1	1	0	3	5

University rankings

	Breakthrough papers	Top 1% papers	Papers cited in top 10% most cited patents
University of Cape Town	1	1	1
Stellenbosch University	2	3	2
University of the Witwatersrand	3	2	3
University of Pretoria	4	5	4
University of KwaZulu-Natal	5	4	5
North West University	6	7	7
University of the Western Cape	7	8	8
University of Johannesburg	8	6	10
Rhodes University	10	9	9
Nelson Mandela Metropolitan University	9	12	11
Durban University of Technology	11	13	14

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University rankings

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University of KwaZulu-Natal	5	4	5
North West University	6	7	7
University of the Western Cape	7	8	8
University of Johannesburg	8	6	10
Rhodes University	10	9	9
Nelson Mandela Metropolitan University	9	12	11
Durban University of Technology	11	13	14
University of the Free State		10	6
Tshwane University of Technology		14	12
University of South Africa		11	15
Cape Peninsula University of Technology		15	13
University of Venda		16	16

Concluding remarks (1)

- SA's number of breakthrough publications significantly increased since 1996
- Large differences between universities
- Large degree of similarity between Breakthrough output, Top 1% highly cited papers output and cited in top 10% most-cited patents output (a mark of excellence ?)
- The University of Cape Town, Stellenbosch University and University of the Witwatersrand score highest on production of breakthrough research papers
- Medical and Life Sciences is the most important area of breakthroughs, especially within General Medicine

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Concluding remarks (2)

- Breakthrough papers come almost exclusive from *SA + Rest of the World*
- SA university publications with only partners from the African continent:
  - Do not show in the top 1% publication output
  - Are almost not cited in top 10% most cited patents, whereas other publications do
- The University of the Free State has papers:
  - in the top 1% publication output
  - cited in top 10% most cited patents

  But has no breakthroughs

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Thank you for your attention!

Are breakthrough papers always highly cited?

A comparison with:

- Top 1% most highly cited publications worldwide per field, per year
- Papers referenced in the top 10% most cited patents worldwide

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Algorithms

- Researchers inflow impact (RII)
- Application-oriented research impact (ARI)
- Cross-disciplinary impact (CDI)
- Discoverers intra-group impact (DII)
- Research niche impact (RNI)

Outline

- Research question
- Identifying breakthroughs
  - What is a breakthrough?
  - Short introduction of the methodology
  - Alternative methods
  - Data sources
- South Africa's scientific breakthroughs
  - Trends over time
  - Most active universities
  - Relevant science areas
  - Organizational collaboration
- Concluding remarks

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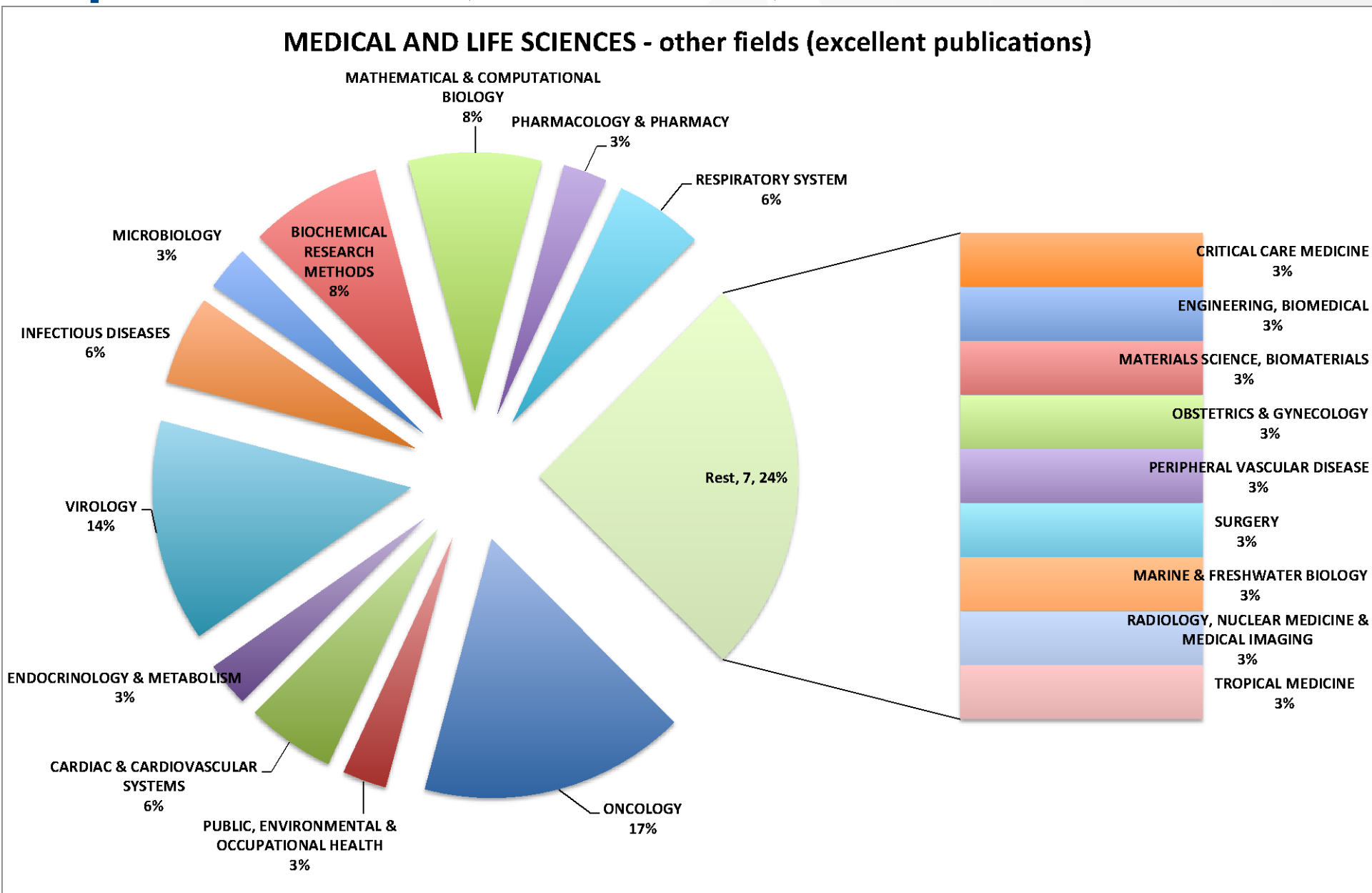
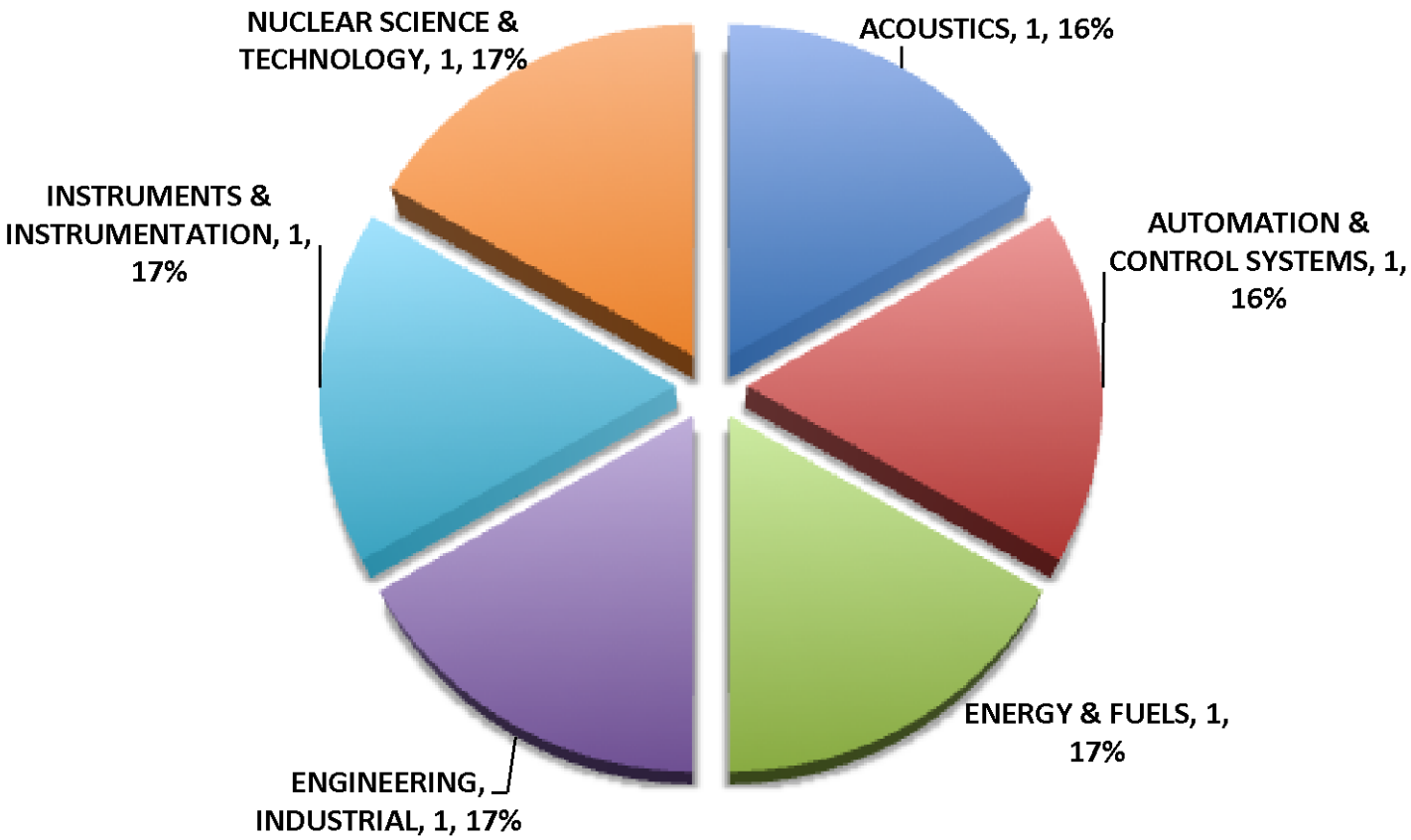
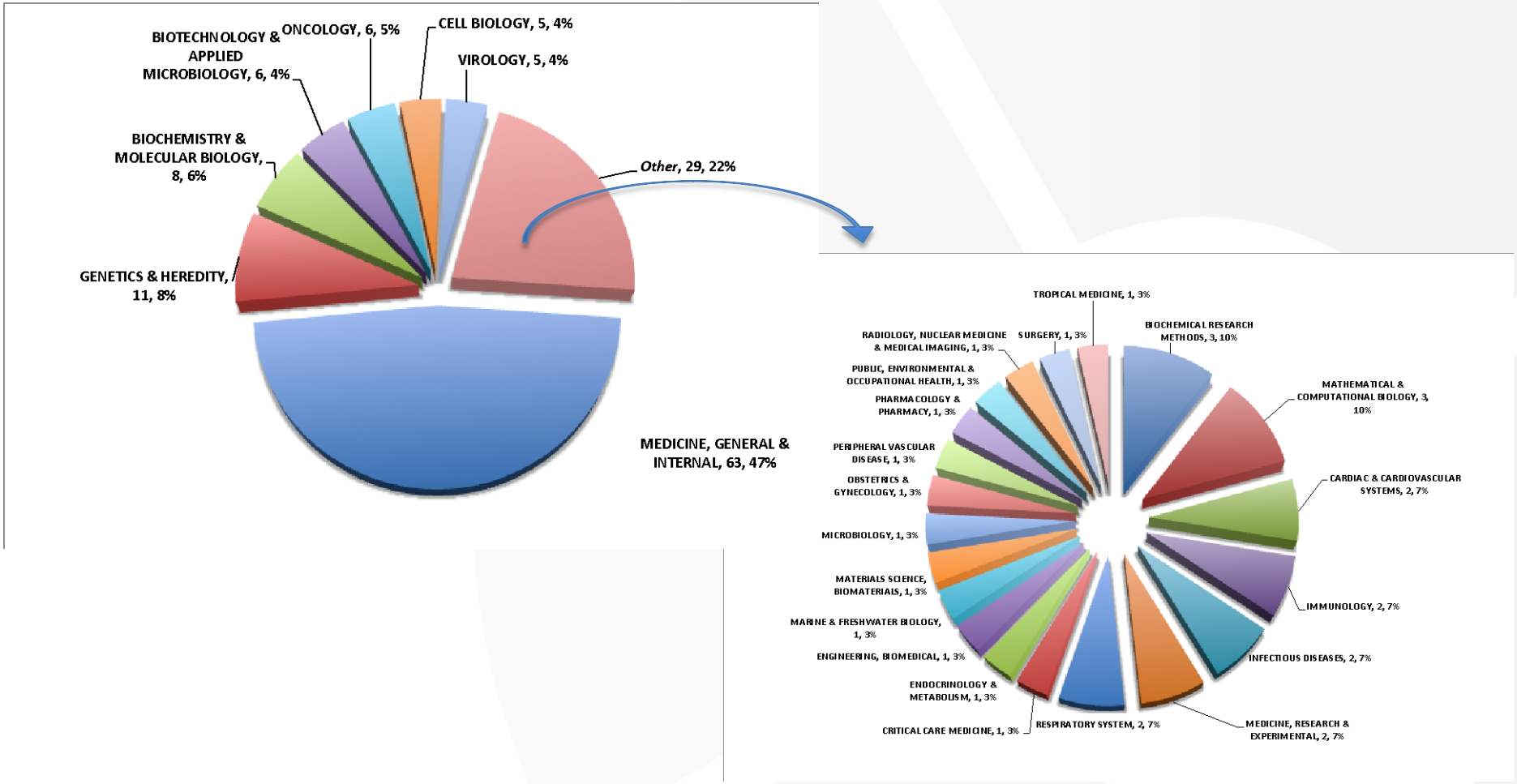
Medical and Life sciences - breakthrough publications (1996-2015) - breakdown



Engineering sciences - breakthrough publications (1996-2015)



Medical and Life sciences - breakthrough publications (1996-2015)



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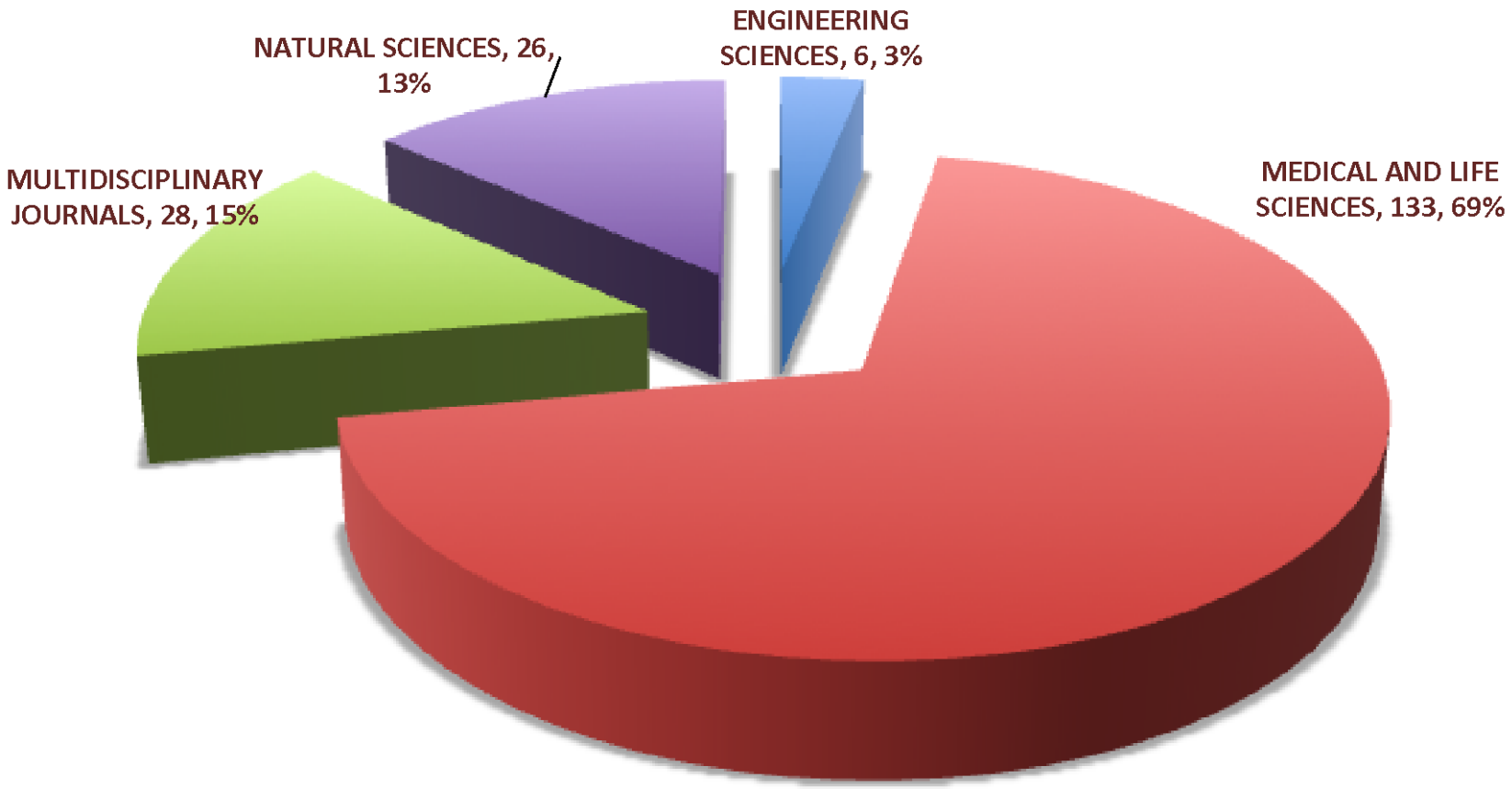
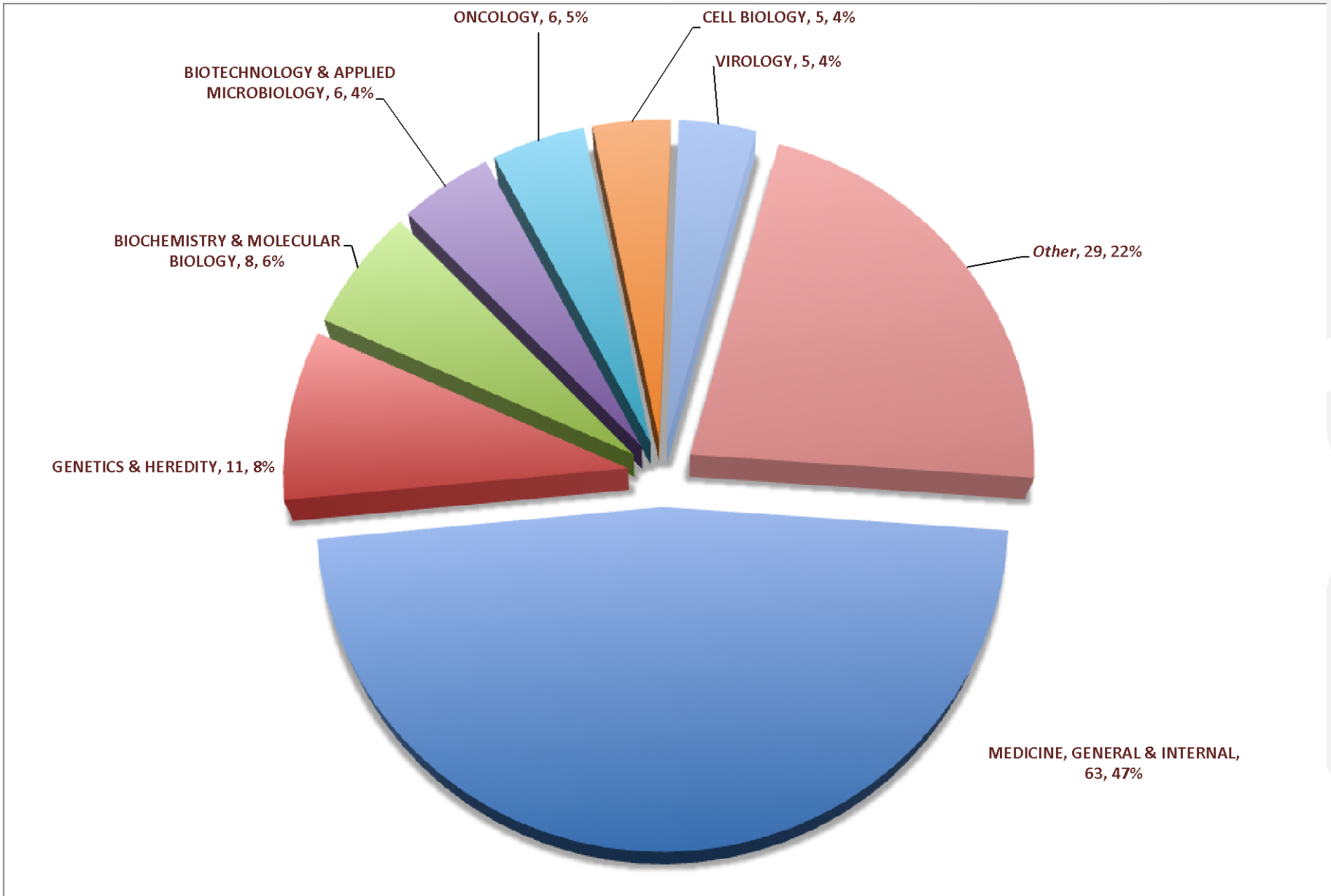
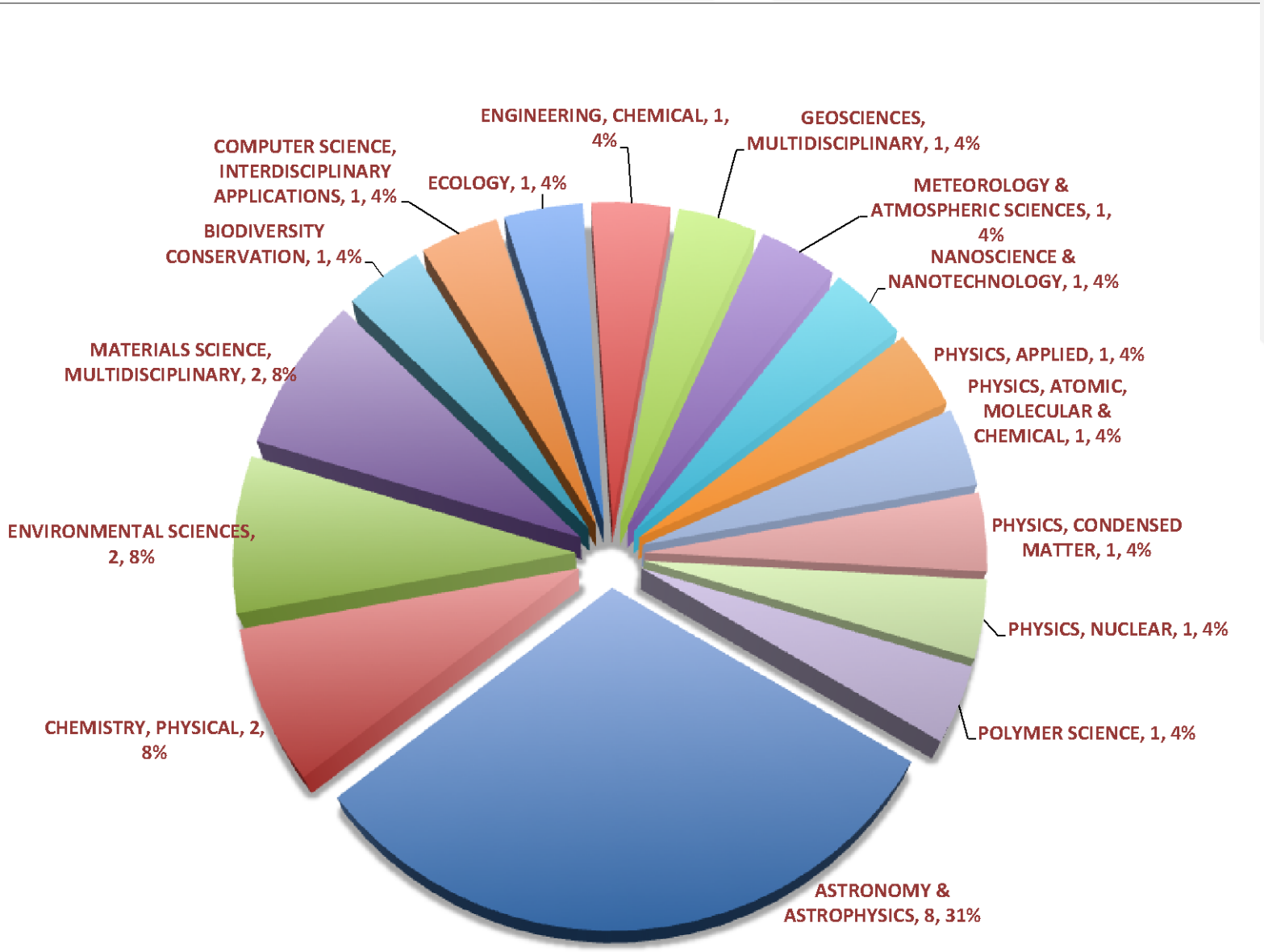
Breakthrough publications across science fields (1996-2015)



Medical and Life sciences - breakthrough publications (1996-2015)



Natural sciences - breakthrough publications (1996-2015)



Top 1% publications, distribution across science fields

	Total	SA single institute	SA domestic	SA + other African country	SA + Rest of the World
Engineering Sciences	***2 (0.2%)***	50%	0%	0%	50%
Language, Information And Communication	***11 (1.0%)***	45%	9%	0%	45%
Law, Arts And Humanities	***3 (0.3%)***	33%	0%	0%	67%
Medical And Life Sciences	***356 (31.4%)***	4%	2%	0%	94%
Multidisciplinary Journals	***40 (3.5%)***	0%	0%	0%	100%
Natural Sciences	***567 (50.0%)***	7%	2%	0%	90%
Social And Behavioral Sciences	***156 (13.7%)***	12%	3%	0%	85%

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Breakthrough algorithms

- Researchers inflow impact (RII)
- Application-oriented research impact (ARI)
- Does the ‘Cross-disciplinary impact (CDI)
- Discoverers intra-group impact (DII)
- Research niche impact (RNI)

Algorithm based methods

- Breakthrough detection algorithms
- Highly cited publications
- Publications cited in patents

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Extensive validation

In a forthcoming publication we show the results of an more extensive validation of our method:

> Winnink J.J., Tijssen, R.J.W. and van Raan, A.F.J. *(to be published in PLoS One)* Can early-detection algorithms of breakout papers uncover scientific breakthroughs?

Our method succeeds select what seem to be the most relevant publications.

Breakouts and all publications (articles & letters from 2007-2011)*

Organisational category	Number of papers	Breakout papers	share
Total	*2,660,300*	*114,778*	*4.2%*
University	1,886,048	79,144	4.2%
Research Institute	225,731	10,046	4.5%
Company	129,950	4,557	3.5%
Hospital	99,178	1,936	2.0%

* Excludes papers that could not be assigned to organisational subcategories

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Breakout and no-breakout papers (1990-1994)*

Organisational category**	All publications (letters & articles)	No breakout	Breakout
University	76.8%	76.8%	77.2%
Research Institute	11.3%	11.3%	**13.1%**
Company	6.4%	6.4%	6.4%
Hospital	5.5%	5.6%	**3.4%**

* No Arts. Humanities and Social Science papers

** Excludes papers that could not be assigned to organisational subcategories

Distribution of breakout papers across NOWT-categories (articles + letters, 2007-2011)*

Organisational category	Medical and Life Sciences	Natural Sciences	Engineering Sciences	Social and Behavioural Sciences	Multidisciplinary journals**
University	73%	81%	78%	91%	75%
Research Institute	13%	14%	14%	6%	15%
Company	7%	4%	8%	2%	7%
Hospital	8%	0%	0%	2%	4%

* Excludes papers that could not be assigned to organisational subcategories
** Journals assigned to this category, by Thomson Reuters, include *Nature*, *Science* and *PNAS*.

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Multidisciplinary journals
(articles & letters, 2007-2011)

Multidisciplinary journal	Number of papers	Number of breakout papers	Breakout papers as share of total number of papers
Nature	13,041	1,966	15.1%
PNAS	20,173	1,758	8.7%
Science	12,744	1,585	12.4%

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