

Nano Bibliometrics

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- ▶ Spotlights
 - Nano Bibliometrics, 1995
 - Nano Bibliometrics, 2015
- ▶ Exploring large search datasets further – a case example:
 - Nano-Enabled Drug Delivery (NEDD), for
 - Cancers

Nano Bibliometrics, 1995

- ▶ Porter, A.L., and Cunningham, S., "Whither Nanotechnology? A Bibliometric Study," *Foresight Update*, No. 21, p. 12-15, 1995.
- ▶ Searched in Science Citation Index (SCI) & *INSPEC*

1986-1995	<u>SCI</u>	<u>INSPEC</u>
Nano-Related:	912	3208
Nanotechnology:	82	584
Scanning Probe Nano:	150	122
Bottom-Up Nano:	32	42

Nano Bibliometrics, 1995

- ▶ Nano growing rapidly
- ▶ *SCI* – frequent terms: nano* [not so much “nanotechnology”], self-assembly, supramolecular

Observations:

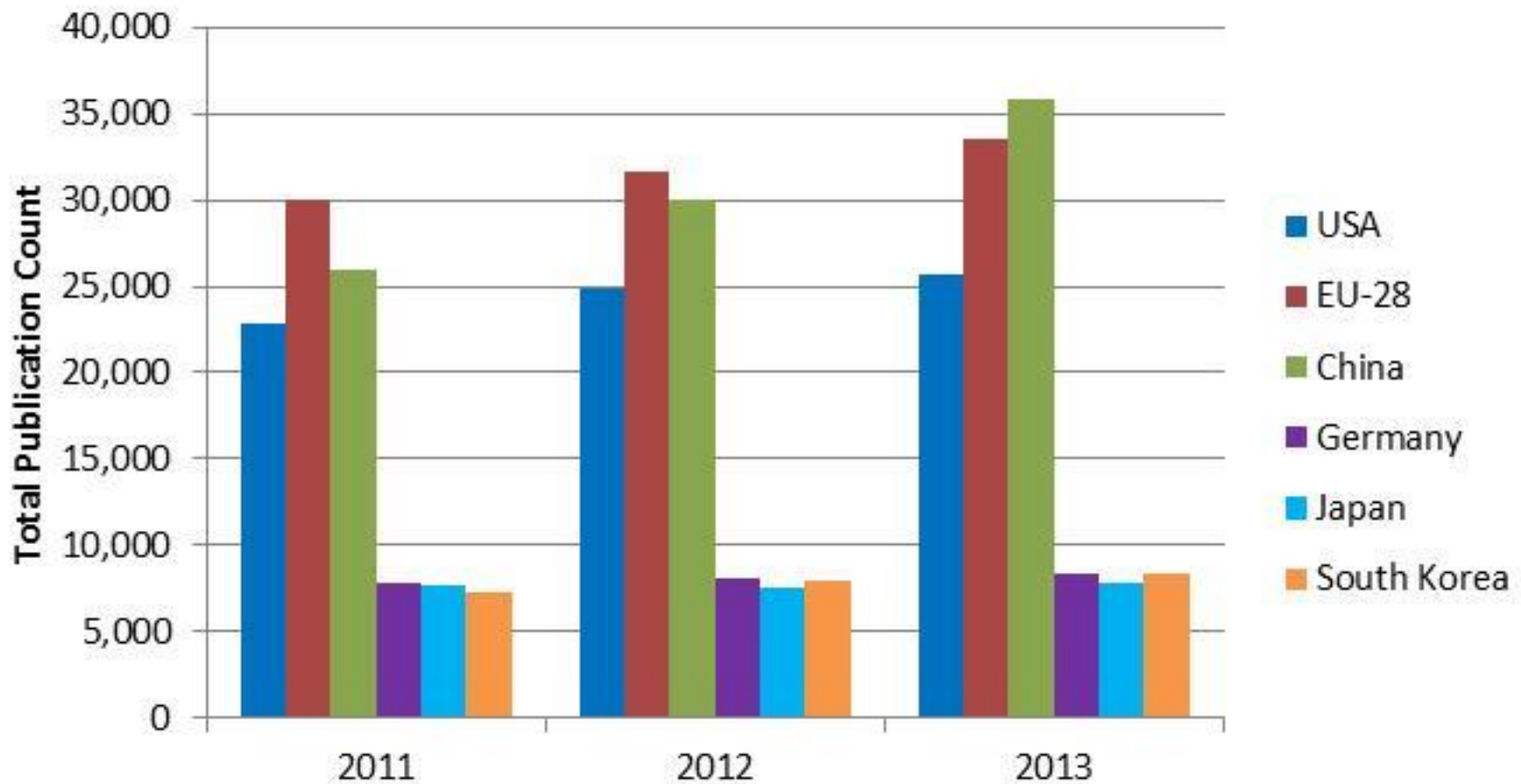
- ▶ Diverging research areas
 - *INSPEC* rich on: semiconductors, lithography, materials science
 - *SCI* rich on: microscopy, biophysics, films, surface sciences
- ▶ Distinct citation patterns
 - E.g., 246 articles cite K. Eric Drexler (*Engines of Creation*, 1986 + more)
- ▶ USA leads; Japan 2d
 - “China active in nano-related”

Nano Bibliometrics, 2015

- ▶ Georgia Tech Program in Science, Technology & Innovation Policy (STIP) has been generating nano datasets for a decade, with support from NSF via the Center for Nano in Society at Arizona State University
- ▶ Searches in various databases, but particularly:
 - *SCI* ~**850,000 publication abstract records** from 1991
 - *PatStat* ~**116,000 patent records**
 - The search algorithm is publicly shared and well-cited
- ▶ Next slides share some highlights prepared for the President's Council of Advisors on Science and Technology (PCAST) 2014 report – The Fifth Assessment of the National Nanotechnology Initiative

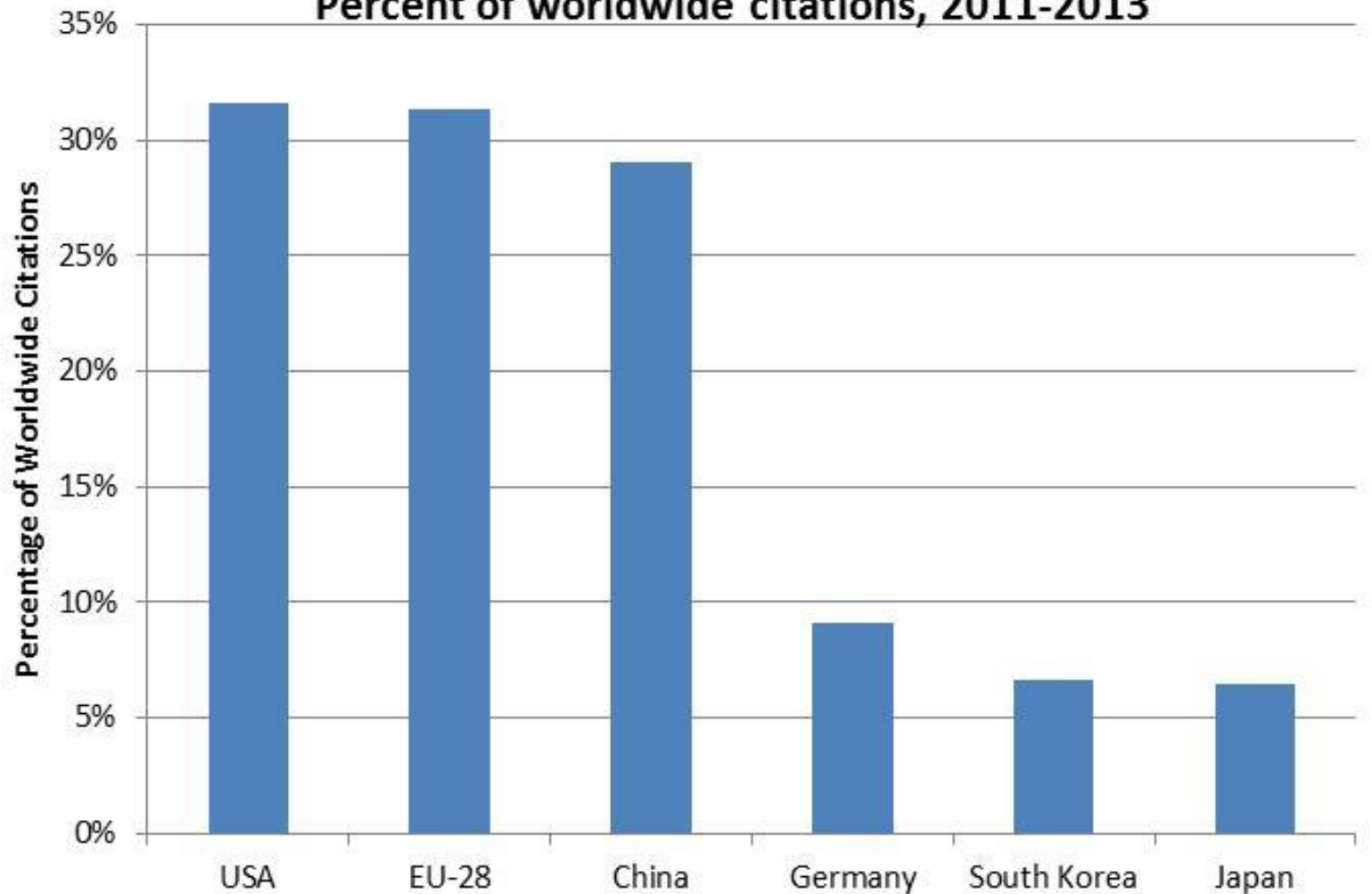
http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_fifth_nni_review_oct2014_final.pdf

Output of nanotechnology papers 2011-2013



Li, Y., Arora, S., Youtie, J., Shapira, P., and Carley, S. (2014), Nanotechnology Publication Counts and Citations: 2011–2013 – for PCAST Report. This material is based upon work supported by the National Science Foundation (NSF) through the Center for Nanotechnology in Society (CNS–ASU) under NSF Grant Number 0937591. Any opinions, findings and conclusions expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the authors' institution.

Citations to nanotechnology papers by author location Percent of worldwide citations, 2011-2013



Li, Y., Arora, S., Youtie, J., Shapira, P., and Carley, S. (2014), Nanotechnology Publication Counts and Citations: 2011–2013 – for PCAST Report. This material is based upon work supported by the National Science Foundation (NSF) through the Center for Nanotechnology in Society (CNS–ASU) under NSF Grant Number 0937591. Any opinions, findings and conclusions expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the authors' institutions.

NEDD: Research Question(s)

Nanotechnology-Enabled Drug Delivery (NEDD) – which A) nano components are helping deliver which B) drugs to treat which C) cancers?

Pointing toward further questions:

- **How to facilitate discovery of such research opportunities?**
- **How might R&D policy/management better “connect” research in adjacent arenas?**

But first, some background on our “tech mining” on NEDD

Simple schematic of the “NEDD dream”

Molecular imaging & therapy

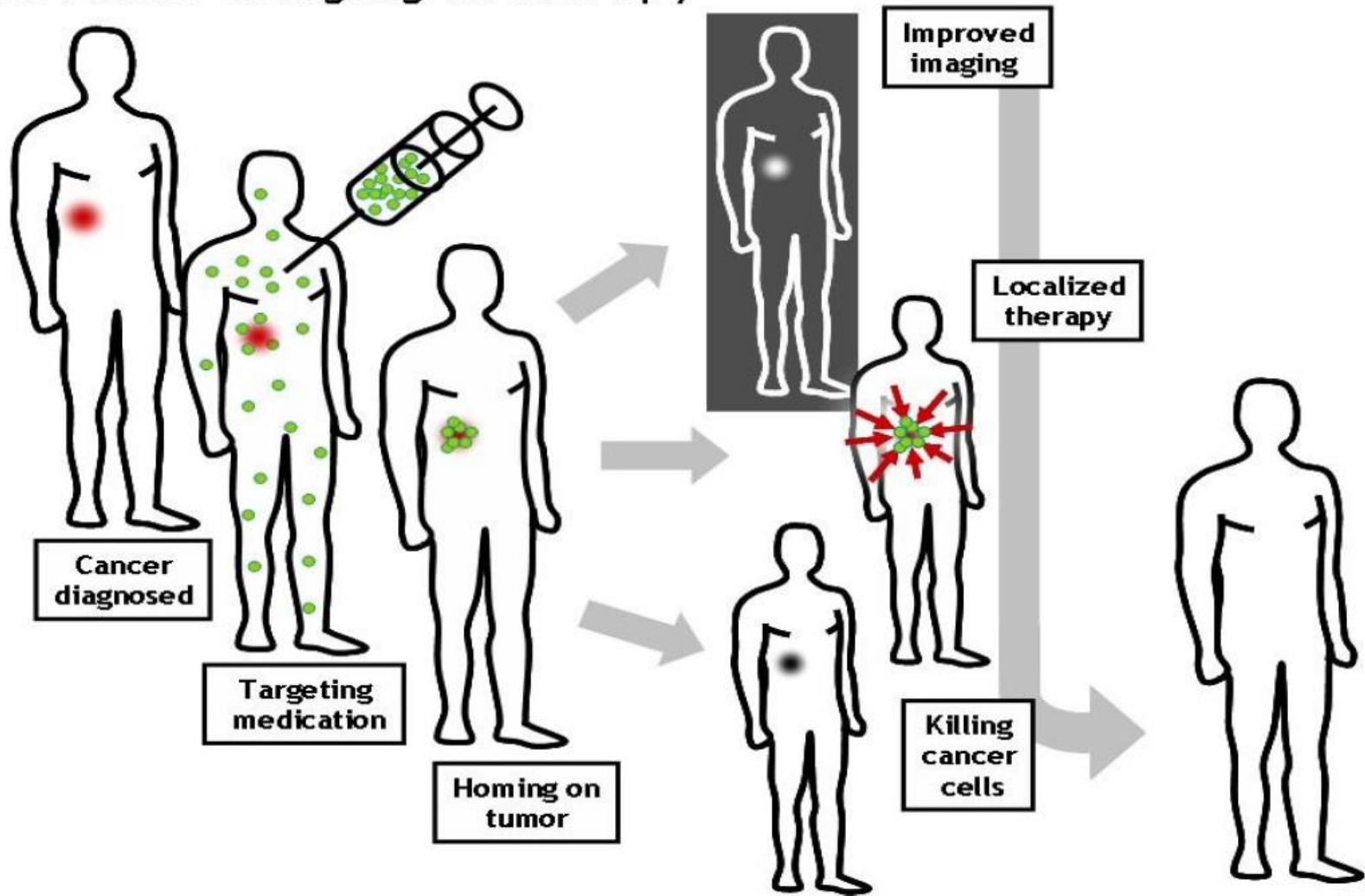
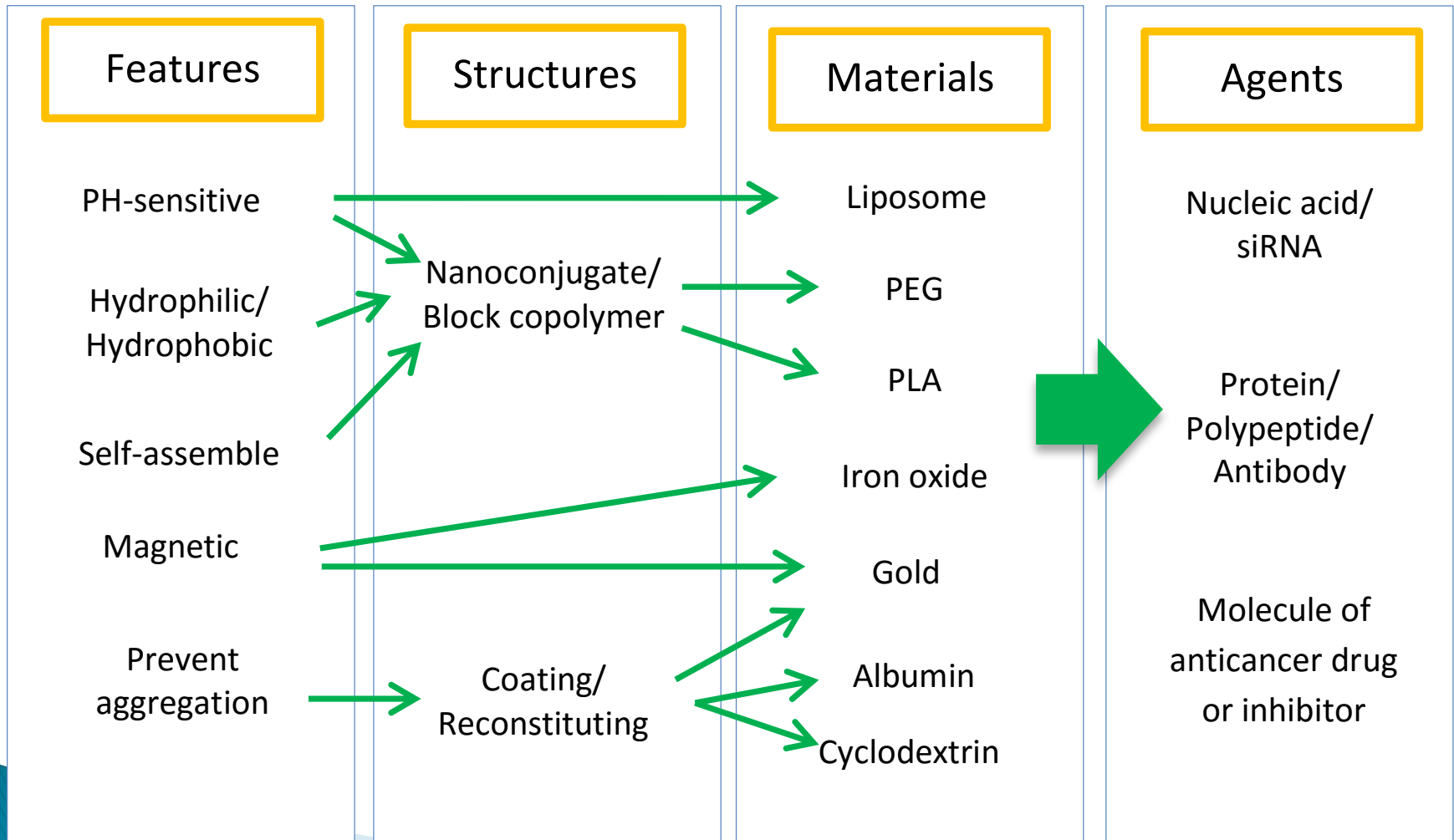


Fig.3: Nanoparticles used to treat cancer

How do “nano” components work to treat diseases like cancer?

[deriving mainly from analyses of the NEDD patents]



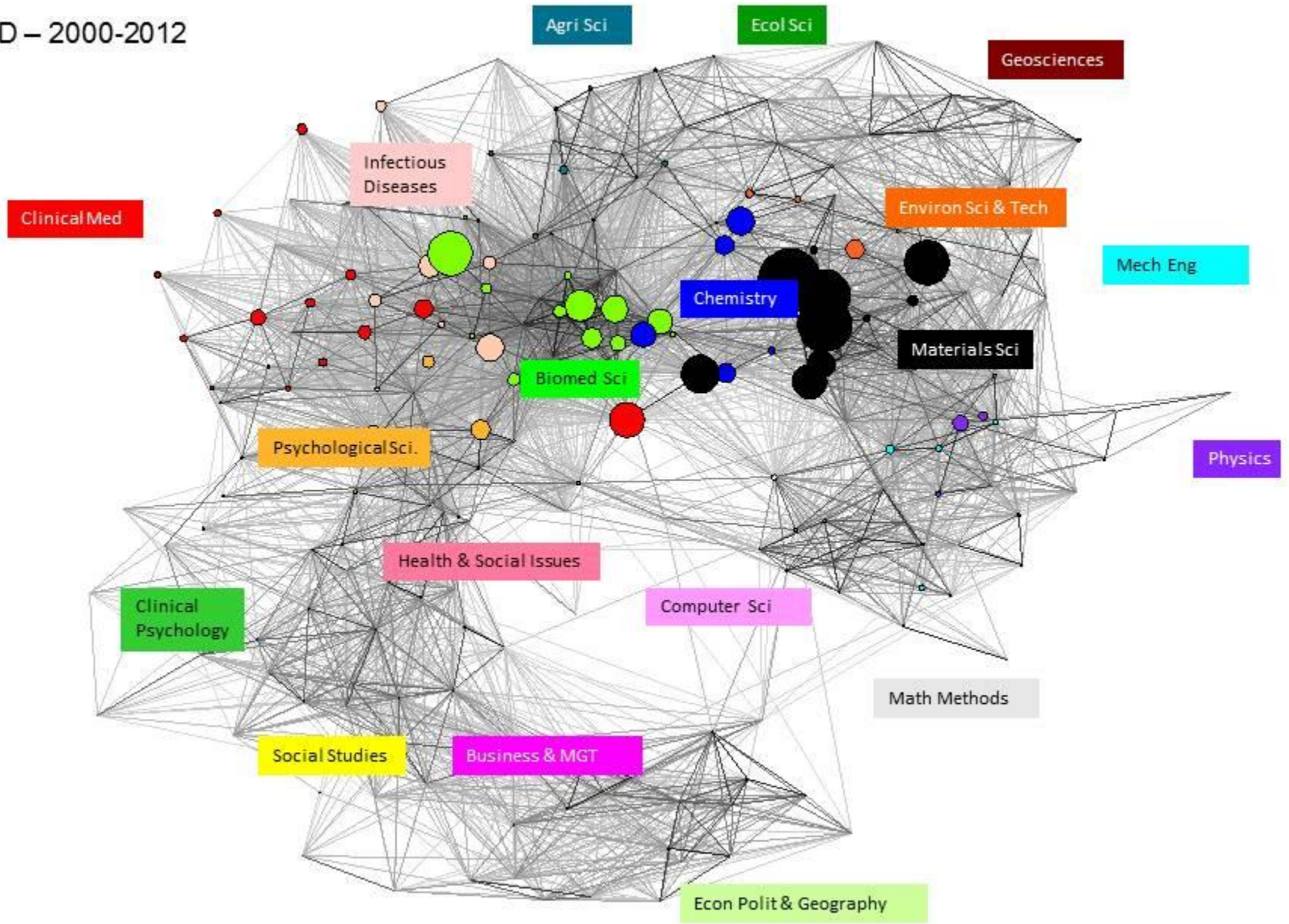
Data & Analyses

Multi-part Boolean search to retrieve NEDD data

- ~60,000 Web of Science publication abstracts
- ~8,000 Derwent Innovation Index abstracts
- ~50,000 MEDLINE publication abstracts
- **~10,000 MEDLINE—NEDD for cancer abstracts**

Global Map of Science, 2010 update 224 Web of Science Categories

NEDD – 2000-2012

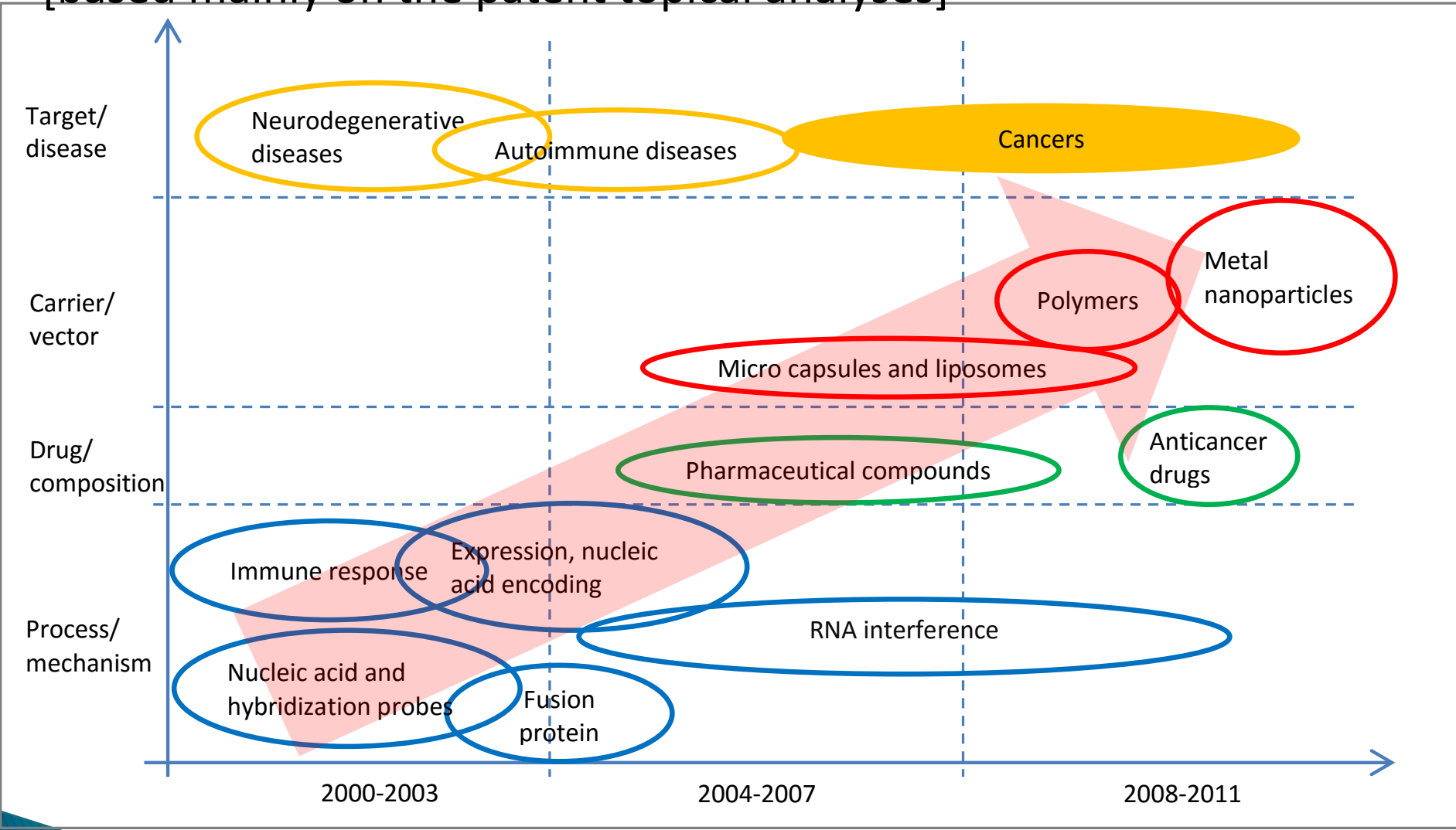


Method from Rafols, Porter and Leydesdorff (2009)



Developmental Pathways, Locating the 13 NEDD Topics of NEDD

[based mainly on the patent topical analyses]

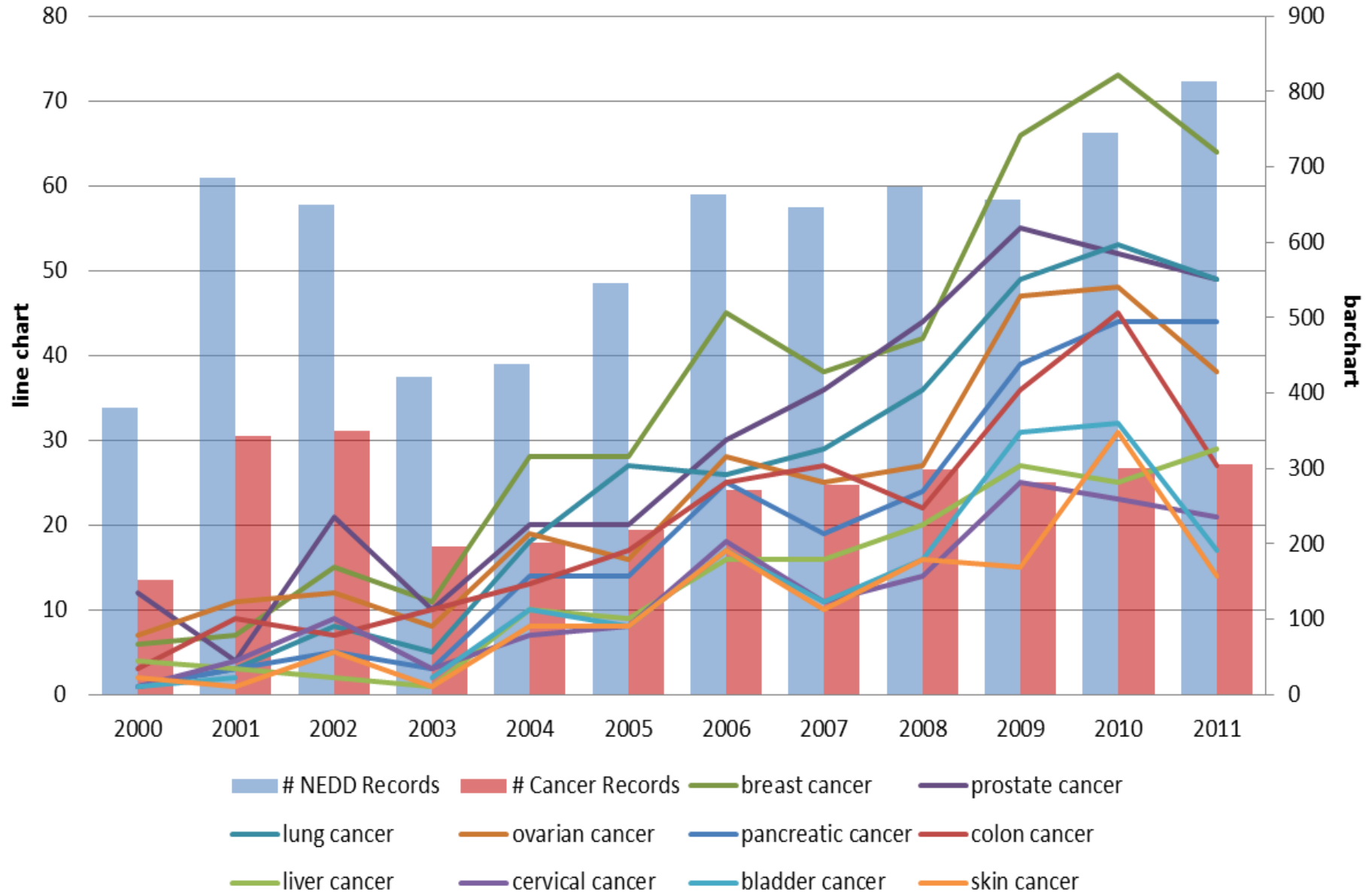


Feedback on the Empirical Research Profiling

Workshop with bio-medical & science policy colleagues at Georgia Tech (and 2d workshop at a Novel Drug Delivery Systems conference) – payoff will come from **focusing on particular nano components and/or targets**

- One path: comparing NEDD for brain applications – Alzheimer's Disease and brain cancer
- **Second path (today's focus) – NEDD for cancer treatments**

Focus on Cancers [patenting patterns]



RESEARCH & DEVELOPMENT	Nano-vector research	<ul style="list-style-type: none"> Polymer-based nanoparticles Lipid-based nanoparticles Ceramic-based nanoparticles Albumin nanoparticles Nanogels Dendrimers
	Vector + drug R&D	<ul style="list-style-type: none"> Liposomes Phospholipids PluronicR Poly (L-aminoacid) with oligonucleotides Polyester micelles Nanoemulsions Drug nanocrystals
EFFICACY & TOXICITY TESTS	Clinical Trials	<ul style="list-style-type: none"> S-CKD602 / PEGyl. Liposome – Alza Corp. CRLX101 / Cyclodextrin – Cerulean Pharma CPX-1 / Liposomal irinotecan – Celator Pharma LE-SN28 Liposoma SN38 – Neopharm NC-6004 / Cisplatin – NanoCarrier Co. ALN-VSP / lipid nanoparticle of siRNA – Alnylam OSI-211 / Liposomeal lurtotecan / OSI Pharma BIND-014 / polymeric NPdocetaxel – BIND Bioscience MBP-426 / Transferrin targetd oxaliplatin – Mebiopharm CALAA-01 / cyclodextrin and siRNA – Calando Pharma SGT53-01 / Liposome with p53 gene – SynerGene Therap.
	Approved on Market	<ul style="list-style-type: none"> Doxil/Caelyx (<i>Breat cancer / leukemia</i>) Abraxane (<i>Breast cancer</i>) Myocet (<i>Ovarian cancer</i>) DaunoXome (<i>Karposi's sarcoma</i>) Genexol-PM (lung and breast cancer (KOREA)) Depocyte (<i>neoplast meningitis</i>)
COMMERCIALISATION		

TODAY

Applications of approved nano-cancer therapies to other cancers

Co-delivery of multiple drugs in one therapy?

Multi-functional nano-enabled drug delivery systems with active targeting?

TOMORROW?

NEDD + Cancers

#	Search Strategy (Web of Knowledge's MEDLINE -- 2000-2013, performed 7/24/14)	NO. of records
#1	MeSH HEADING:exp: (Neoplasms OR Antineoplastic Agents) AND (Drug carriers OR Micelles)	8715
#2	((MeSH HEADING:exp: (Neoplasms OR Antineoplastic Agents) AND Nanostructures) NOT #1) AND MeSH HEADING: (Drug Delivery Systems OR RNA Small Interfering OR Gene Transfer Techniques OR Delayed-Action Preparations OR RNA Interference OR Pharmaceutical Vehicles OR Genetic Vectors OR Transfection OR Polyglycolic Acid)	1517
#3	(((((MeSH HEADING:exp: (Neoplasms OR Antineoplastic Agents) AND Nanostructures) NOT #1) AND MeSH HEADING: (Doxorubicin OR Polyethylene Glycols OR Paclitaxel)) NOT #2) AND ABSTRACT/TITLE: deliver*	122
#4	Total	10354

Mining the Data

- ▶ Use VantagePoint desktop software (www.theVantagePoint.com) to separate ~3334 primary MeSH terms and 73 Qualifiers in those 10,354 abstract records
- ▶ Focus on top **200 primary MeSH terms** and **73 Qualifiers** = matrix
- ▶ SPSS Hierarchical Clustering to consolidate those 200 MeSH terms into 7 clusters
 - **Drug** – drugs and formulas
 - **Component** – nanoparticles and accompanied materials
 - **Cancer** – different cancer types
 - Method – techniques, procedures, and programs
 - Effect – effects of treatment
 - Interface – receptors and metabolism
 - Antibody – antibodies and antigens

Happy Hunting Grounds!

- ▶ Explore co-occurrences
- ▶ 3 key relationships to explore:
 - **Cancers (20) by Drugs (50)**
 - **Cancers (20) by Nano components (62)**
 - **Drugs (50) by Nano components (62)**
- ▶ But really more than 2-D – additional dimensions to explore – e.g.:
 - Nano Components – which are getting specialized use vs. broad use?
 - When [which topics are hot]?

	3879	Col Sum	704	580	248	224	89	319	238	224	23
		# Records	2697	1476	713	430	212	864	761	290	42
# Records	CANCERS \ AGENTS	Antineopl	Doxorubici	Paclitaxel	RNA, Sma	DNA	Antibiotics	Antineopla	Antineopla	Adjuvants, PI	
1	627	Breast Neoplasms	0.79	1.51	1.37	0.83	0.42	1.34	0.94	1.52	0.27
2	490	Brain and Nerve Neoplasms	1.02	0.78	1.12	0.85	1.16	0.77	1.00	0.53	0.69
3	397	Liver Neoplasms	0.96	1.43	0.59	1.00	1.76	1.72	0.86	0.26	0.85
4	376	Lung Neoplasms	1.10	0.80	1.33	1.70	1.16	0.81	1.30	0.88	0.90
5	356	Skin Neoplasms	1.05	0.83	0.53	0.78	1.59	0.75	0.96	0.34	3.32
6	269	Colorectal Neoplasms	1.09	0.72	0.70	0.52	0.32	0.54	1.33	0.71	1.25
7	237	Ovarian Neoplasms	1.05	1.50	2.11	1.46	0.55	1.74	1.31	2.41	0.00
8	208	Prostatic Neoplasms	0.90	0.71	0.38	2.41	1.26	0.47	0.63	0.50	0.81
9	133	Adenocarcinoma	0.91	0.75	0.82	0.65	1.31	0.82	0.74	1.82	1.27
10	131	Leukemia	0.72	0.36	0.12	0.13	0.33	1.58	1.00	2.51	0.00
11	122	Pancreatic Neoplasms	1.45	0.22	0.77	0.71	2.14	0.20	0.94	1.28	0.00
12	114	Carcinoma, Squamous Cell	0.77	0.47	0.69	0.61	0.76	0.43	0.71	1.37	0.00
13	79	Stomach Neoplasms	0.91	0.25	1.78	1.10	0.55	0.62	1.86	1.10	0.00
14	67	Bone Neoplasms	1.40	1.90	0.47	1.29	0.65	0.73	0.00	1.29	0.00
15	59	Head and Neck Neoplasms	1.21	1.13	0.27	0.88	0.00	1.03	0.00	1.17	0.00
16	53	Urinary Bladder Neoplasms	1.04	0.76	2.95	1.63	0.00	1.38	1.85	0.00	3.18
17	51	Peritoneal Neoplasms	1.94	0.92	1.23	0.00	0.85	0.72	1.60	0.34	0.00
18	38	Uterine Cervical Neoplasms	0.87	0.70	1.65	1.37	3.44	0.64	0.86	0.91	8.88
19	37	Lymphoma	0.74	0.90	0.00	0.47	0.00	0.66	0.88	0.00	4.56
20	35	Sarcoma	1.57	2.87	0.45	0.00	1.25	1.39	0.47	1.98	4.82

Agent profiling: DOX -- Used for all 20; sarcoma & bone neoplasm most:
Paclitaxel used for all but one (lymphoma) - why not?

Cancer profiling: Leukemia - 5 drugs overwhelmingly used to treat this
- see earlier matrix

Agent for Cancer; Explore the zeroes with biomedical scientists

3879	Col Sum	704	580	248	224	89	319	7
	# Records	2697	1476	713	430	212	864	45
# Records	CANCERS \ AGENTS	Antineoplas	Doxorubici	Paclitaxel	RNA, Sma	DNA	Antibiotics	Etoposide
627	Breast Neoplasms	0.79	1.51	1.37	0.83	0.42	1.34	0.88
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376	Lung Neoplasms	1.10	0.80	1.33	1.70	1.16	0.81	2.95
356	Skin Neoplasms	1.05	0.83	0.53	0.78	1.59	0.75	0.00
269	Colorectal Neoplasms	1.09	0.72	0.70	0.52	0.32	0.54	0.00
237	Ovarian Neoplasms	1.05	1.50	2.11	1.46	0.55	1.74	0.00
208	Prostatic Neoplasms	0.90	0.71	0.38	2.41	1.26	0.47	0.00
133	Adenocarcinoma	0.91	0.75	0.82	0.65	1.31	0.82	0.00
131	Leukemia	0.72	0.36	0.12	0.13	0.33	1.58	0.00
122	Pancreatic Neoplasms	1.45	0.22	0.77	0.71	2.14	0.20	0.00
114	Carcinoma, Squamous Cell	0.77	0.47	0.69	0.61	0.76	0.43	0.00
79	Stomach Neoplasms	0.91	0.25	1.78	1.10	0.55	0.62	0.00
67	Bone Neoplasms	1.40	1.90	0.47	1.29	0.65	0.73	0.00
59	Head and Neck Neoplasms	1.21	1.13	0.27	0.88	0.00	1.03	0.00
53	Urinary Bladder Neoplasms	1.04	0.76	2.95	1.63	0.00	1.38	0.00
51	Peritoneal Neoplasms	1.94	0.92	1.23	0.00	0.85	0.72	0.00
38	Uterine Cervical Neoplasms	0.87	0.70	1.65	1.37	3.44	0.64	0.00
37	Lymphoma	0.74	0.90	0.00	0.47	0.00	0.66	29.95
35	Sarcoma	1.57	2.87	0.45	0.00	1.25	1.39	0.00

Examine **groups** of agents or cancers: genetic treatments [RNAi & DNA] – notably widely used.

Crosswalk: explore why RNAi is not showing for peritoneal neoplasms, but DNA is? Also, DNA is prominent for uterine cervical, why less so RNAi? Look at **narrowly targeted** agents; might they hold potential for others?

20 Cancers by 50 Drugs: Added Dimensions Ex. 29 articles on RNAi for Prostate

File Edit View Sheets Fields Groups Tools Scripts Window Help

cancer-drug

29 Titles, 1 Selected

Enhanced docetaxel-mediated...
A non-covalent peptide-based...
Anisamide-targeted cyclodext...
Atu027, a liposomal small inte...
Cover story. RNA interference (...
Delivery of multiple siRNAs usi...
Efficient delivery of small inter...
Efficient delivery of sticky siRN...
Inhibitory effect of silencing S...
Intracellular siRNA delivery sys...
Lipid nanoparticle siRNA syste...
Local and systemic delivery of ...
PAMAM dendrimers mediate s...
PEG conjugated VEGF siRNA f...
Plasmid-based Stat3 siRNA de...
Polymeric nanoparticles for su...
Prostate cancer cell death pro...
Prostate-targeted biodegrada...
PSA-responsive and PSMA-me...
Redox-active polymer microca...
Reducible poly(amido ethyleni...
RNA interference in the mouse...
siRNA transfection with calci...
Solid lipid-PEI hybrid nanocar...
Systemic delivery of RafsiRNA ...
Systemic delivery of therapeut...
Targeting ECM-integrin intera...
Therapeutic delivery of siRNA ...
Well-defined degradable cati...

MeSH Terms (Primary) (1):	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	28	
# Records	2697	1476	713	430	212	864	761	290	42	73	233	110	162	176	273	272	172	172	139	133	100	103	100	86	85	63	5	
MeSH headings (1)																												
MeSH Terms (Primary) (1): MeSH headings (1)																												
# Records																												
Antineoplastic Agents																												
Doxorubicin																												
Paclitaxel																												
RNA, Small Interfering																												
DNA																												
Antibiotics, Antineoplastic																												
Antineoplastic Agents, Phytogetic																												
Antineoplastic Combined Chemotherapy Prot																												
Adjuvants, Immunologic																												
Plasmids																												
Cisplatin																												
Curcumin																												
Photosensitizing Agents																												
theicin																												
abolites, Antineoplastic																												
ies, Monoclonal																												
racil																												
sis Inhibitors																												
Vectors																												
ibicin																												
exate																												
ine																												
platinum Compounds																												
neoplastic Agents, Alkylating																												

1 627 Breast Neoplasms 90 142 55 30 6 69 36 55 5 5 10

2 490 Brain and Nerve Neoplasms 91 57 35 24 13 31 30 15 6 9

3 397 Liver Neoplasms 69 85 15 23 16 56 21 6 7 11

4 376 Lung Neoplasms 75 45 32 37 10 25 30 19 16 7

5 356 Skin Neoplasms 68 44 12 16 13 22 21 7 7 5

6 269 Colorectal Neoplasms 53 29 12 8 12 22 11 7 9

7 237 Ovarian Neoplasms 45 53 32 20 34 19 33 24 5

8 208 Prostatic Neoplasms 34 22 5 29 6 8 8 6 7 5

9 133 Adenocarcinoma 22 15 7 5 9 6 14 8 5 6

10 131 Leukemia 17 7 17 8 19 11 26 21 10

11 122 Pancreatic Neoplasms 32 6 5 6 7 9 9 5

12 114 Carcinoma, Squamous Cell 16 8 5 5 9 7 6

13 79 Stomach Neoplasms 13 9 5 9 5 6

14 67 Bone Neoplasms 17 19 5 5

15 59 Head and Neck Neoplasms 13 10 5

16 53 Urinary Bladder Neoplasms 10 6 10 5 6 6

17 51 Peritoneal Neoplasms 18 7 5

18 38 Uterine Cervical Neoplasms 6

19 37 Lymphoma 5 5

20 35 Sarcoma 10 15

Hot!

Using which nano components?

+ other cancers?

+ other drugs (multi-drug delivery?)

Publication Year

Nano Components 62

6	Nanoparticles
3	Nanocapsules
3	Polyethylene Glycols
2	Lipids
2	Polyethyleneimine
1	Aptamers, Nucleotide
1	beta-Cyclodextrins
1	Cell-Penetrating Peptid
1	Coated Materials, Bioco
1	Dendrimers
1	Liposomes
1	Oligopeptides
1	Peptides
1	Polyamines

Cancers (20)

29	Prostatic Neoplasms
2	Bone Neoplasms
1	Pancreatic Neoplasms

Agents (drugs) 50

29	RNA, Small Interfering
1	Antibiotics, Antineoplastic
1	Antineoplastic Agents
1	Doxorubicin
1	Taxoids

NEDD ca...

50 Agents (Drugs) by 62 Nano Components

Address 4958 of the 10,354 articles; spotlighted a row (one agent) – 430 articles on “RNA, small interfering”

VantagePoint - [NEDD cancer - 10354-aug6 from Jing.vpt]

File Edit View Sheets Fields Groups Tools Scripts Window Help

drug-component

315 Titles, 0 Selected

Reset MeSH Terms (Primary) (1): MeSH heading # Records

MeSH heading	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Antineoplastic Agents	568	725	298	63	73	23	208	163	48	56	66	102	47	40	136	27	26	55	6	54	43	32	27	14	59	52
Doxorubicin	223	394	136	61	19	5	177	98	42	43	34	38	28	24	83	15	21	48	8	27	31	26	14	10	30	33
Antibiotics, Antineoplastic	127	266	66	5	17	4	105	51	24	25	19	22	13	10	51	7	9	30	5	10	13	11	6	5	11	23
Antineoplastic Agents, Phytogetic	175	266	38	13	19	2	92	54	6	42	7	28	6	2	57	8	8	40		28	5	5	15	3	32	23
Paclitaxel	197	249	24	29	19	2	78	73	11	37	10	31	10	4	75	10	8	47	4	31	2	6	3	35	22	
RNA, Small Interfering	130	60	32	27	23	22	22	21	18	17	13	11	11	9	9	7	7	6	5	5	5	4	4	4	4	4
Antineoplastic Combined Chemotherapy Prot.	25	24	12	11	6		11	5		1																
Campthothecin	54	76	31	13	6		40	14	2	14																
Antimetabolites, Antineoplastic	43	83	16	3	2		16	11	4	19																
Cisplatin	37	64	26	11	2	3	18	10	1	2																
DNA	42	34	30	18	17	13	15	14	9	8																
Taxoids	45	64	8	13	7		19	8	3	11																
Antibodies, Monoclonal	22	32	28	5	4	2	19	5	1																	
Fluorouracil	36	55	7	7	3		13	9	1	13																
Photosensitizing Agents	28	29	13	10	2		11	4	1	3	5	3	1	4	9		1	1								
Prodrugs	23	39	8	4	4		15	8	5	2	4	3	2	1	6	1	1	2			4	1				4
Angiogenesis Inhibitors	15	22	13	1	2		10	3	5	1	6	4	9	1					1		4	1				2
Curcumin	30	33	8	11	3	2	9	3	8	1	7	1	8	3	3	6	2	3								6
Genetic Vectors	17	8	15	2	4	3	6	3	3	4	4	3	1					1								1
Oligonucleotides, Antisense	13	9	16	2	2	2	3	1	1	7																1
Daunorubicin	4	12	8	3	2		1	1	3	2																1
Methotrexate	17	38	1	2	4		9	3	1	5	21															1
Cytarabine	4	6	18	3	3	2	9	3	2	1	1															1
Organoplatinum Compounds	10	18	11		1		9	5		1																2
Deoxycytidine	14	22	11	7	2		4	2	1	6																4
Plasmids	7	7	15	3	4	4	7	1	2	1	4	4		1	3					3	2					1
Porphyrins	4	11	4	1		3	2		1	4	1			2	6											1
Vincristine	3	8	18	1	2		5																			3
Peptide Fragments	5	14	10	2	1		4	2	2			1														2
Antineoplastic Agents, Alkylating	4	18	2	1	1		7	6				1	1		1											4
Organometallic Compounds	6	7	8	2	2		2	3			2	1		1	3											1
Radio pharmaceuticals	8	9	7		1		5	2																		2
Amphotericin B			3				1																			1
Mitoxantrone	8	8	9	3	2		5																			1

Hot!

Using which nano components?

For which cancers?

Only 10 also entail DNA?

Publication Year

Nano Components 62

Cancers (20)

Agents (drugs) 50

Select References

- ▶ Arora, S. Porter, A.L., Youtie, J., Shapira, P. (2013), Capturing new developments in an emerging technology: an updated search strategy for identifying nanotechnology research outputs, *Scientometrics* 95 (1), 351-370.
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Discussion??

Can we “discover” opportunities via such tech mining?

- Research gap analyses – could nano component X also facilitate delivery of treatment Y, for disease Z?
 - ❖ Could such R&D profiling/parsing help in your studies?
 - ❖ How do you learn about “one step removed” research findings, methods, applications, etc.?

Information Resources

- Contact me: Alan Porter: 404-384-6295;
aporter@searchtech.com
- Lots of our papers:
www.researchgate.net/profile/Alan_Porter4
- Providing a paper on this soon
- Software -- www.theVantagePoint.com
- NIH Library has 5-seat license server – for information: Lu, Ya-Ling (NIH/OD/ORS) [E] ya-ling.lu@nih.gov
- We are glad to provide webex support to learn how to use it (and/or visit as mutually scheduling works)