MEETING REPORT

Outcomes and Lessons From the First CDRI-NRDC-Industry Conclave

SABYASACHI SANYAL, SAMAN HABIB, RITU TRIVEDI, K V SASHIDHARA, KISHOR MOHANAN and AMIT MISRA

CSIR-Central Drug Research Institute, Sector 10A, Janakipuram Extension, Sitapur Road, Lucknow, Uttar Pradesh 226 031, India

Email: amit_misra@cdri.res.in

DIALOGUE
Science, Scientists, and Society

Dialogue – Science, Scientists, and Society (2018)

MEETING REPORT

Outcomes and Lessons From the First CDRI-NRDC-Industry Conclave

SABYASACHI SANYAL, SAMAN HABIB, RITU TRIVEDI, K V SASHIDHARA, KISHOR MOHANAN and AMIT MISRA
CSIR-Central Drug Research Institute, Sector 10A, Janakipuram Extension, Sitapur Road, Lucknow, Uttar Pradesh 226 031, India
Email: amit_misra@cdri.res.in

DOI : 10.29195/DSSS.01.01.0002

Abstract

The first Industry Conclave organized jointly by the CSIR-CDRI and the National Research Development Corporation (NRDC) was held on 15–16 September 2017. This document summarizes the learnings from the formal panel discussions conducted during the meeting, as well as interactions among the delegates during the exhibition that showcased the CDRI product pipeline, services offered and proposals for collaborative R&D. It became evident during the course of the conclave that although there was broad consensus on the societal and intellectual value of pursuing 'basic' science, there is a significant 'trust deficit' between the Indian academia and the Industry. Research funding and its sources, and evaluation of research output continue to be contentious.

Keywords. Pharmaceutical Industry; Drug Discovery; Industry-Academia Interaction; Research Priorities; Funding; Science Policy.

Introduction

This document was initially written to serve as an *aide-mémoire* for CSIR-CDRI's effort to engage more meaningfully with the pharmaceutical industry. Such engagement, of necessity, requires that a broad range of issues and concerns be discussed freely, so that the interrelationship between CSIR-CDRI, other academic and research institutions and the pharmaceutical industry can be placed on firm footing. Acknowledging the obvious way in

which CSIR-CDRI can interact with the industry, *viz.,* providing readymade technologies, services, human resources and consultancy, an attempt is made to increase the ambit of this discussion by flagging issues that lie at the core of such interactions. This document is therefore offered as a starting point for further engagement between the academic and industrial research communities in the pharmaceutical and health sciences on the one hand; and the management/policy community relating to the pharmaceutical industry on the other. We hope that clinicians and public health policy professionals would also be drawn into the debate.

The major part of this document, therefore, is a summary of Panel Discussions. Despite differences in the stated themes of the three Panel Discussions, there was an understandable overlap in insights and arguments put forward by the panellists. This was anticipated, since the three broad themes are interlinked. For the purpose of this report, statements have been classified under the most relevant theme regardless of the panel in which they were advanced. Statements have been summarized without attribution, and in a rough order of chronology, without any attempt at prioritization. A 'recommendatory' tone is also deliberately avoided. Additional documentation relevant to some of the points made is provided in the form of notes and citations for the interested reader.

The Panels

Three panels were assembled and were constituted as follows

Basic Research is the Foundation for Innovation	**Technology Transfer: Industry Expectations and Concerns**	**Funding and Costing for Collaborative Drug Discovery and Development**
Panellists		
Prof. N K Ganguly, Ex-DG, ICMR, Visiting Professor, THSTI, Faridabad **Dr. Uday Saxena**, Mentor-in-Chief and Professor, Dr. Reddy's Institute of Life Sciences, Hyderabad **Prof. P Balaram**, Former Director, Indian Institute of Science, Bengaluru **Dr. Satyajit Rath**, Agharkar Chair, Agharkar Research Institute, Pune **Dr. Madhu Dikshit**, Director, CSIR-CDRI, Lucknow	**Dr. Vijay Chauthaiwale**, Ex VP, Torrent Pharma, New Delhi **Mr. Anil Raghavan**, CEO, SPARC, Mumbai **Dr. D B A Narayana**, CSO, Ayurveda Trust, Bengaluru **Dr. Anil Koul**, Director, CSIR-IMTech, Chandigarh **Dr. Gopal Pande**, Director, Ortho Regenerics Private Limited, Hyderabad **Dr. H Purushotham**, CMD, NRDC, New Delhi **Dr. Naibedya Chattopadhyay**, Chief Scientist, CSIR-CDRI, Lucknow	**Dr. D Yogeswar Rao**, Former Adviser, O/o PSA to GoI and former Head, TNBD Division, CSIR, New Delhi **Dr. P K S Sarma**, Head Technical, BIRAC, New Delhi **Dr. Ramesh Byrapaneni**, MD, Endiya Partners, Hyderabad **Prof. Dinesh Kumar Abrol**, Institute for Studies in Industrial Development, New Delhi **Mr. Ashish Jagyasi**, Investment Manager, APIDC VenturEast Fund Advisers Pvt. Ltd. Chennai **Dr. Madhu Dikshit**, Director, CSIR-CDRI, Lucknow **Dr. Amit Misra**, Senior Principal Scientist, CSIR-CDRI, Lucknow

Basic Research is the Foundation for Innovation

None of the panellists had any major disagreement with the basic proposition. However, many underlying nuances emerged very effectively and are as follows.

The concept of a linear, stepwise progression from 'basic' to 'applied' to 'translational' or 'developmental' research is flawed. The mechanism of action of nitric oxide in its multifarious roles in Biology became known much after angina drugs like glyceryltrinitrate had long been in use (Marsh and Marsh 2000). The linkages between Streptococcal pharyngitis, rheumatic fever and rheumatic heart disease were revealed by studies on the variations in immune responses of different patients (Wahi *et al.*, 1989). Statins were discovered in the quest for an inhibitor of microbial HMG CoA reductase for use as an anti-microbial agent (Endo, 1992). Endo explicitly states that the search was for an antimicrobial agent, referring to his own research initiated in 1971 in Japan. However, a more recent review (Tobert 2003) does not refer to this. These examples and the individual and collective experience of the panellists, reinforce the view of research as an end in itself. Outcomes that are useful in a societal or commercial sense arise as offshoots of a general growth in knowledge. Multi-directionality and turbulence are essential for good research. Transformative inventions do not draw on a single linear pathway of mechanistic enquiry but rely on an entire gamut of knowledge.

Recognizing 'innovation' is difficult. The very first experiments conducted with the aim of generating visible images of objects by means of manipulating the magnetic field, or to explore nuclear magnetic resonance in more than one spatial dimension produced results that were not immediately striking (Lauterbur 1989). However, these led to the development of MRI, 2-D and 3-D NMR, etc. Path-breaking work is often recognised only in retrospect. In the short term, it should suffice if 'good' science can be distinguished from 'bad' science. Since 'innovation' is difficult to recognize early on, 'discovery' and 'invention' should be sought instead, although the distinction between discovery and invention is often artificial.

Research is not amenable to being 'directed.' It is best if research objectives defined by policymakers and the industry are simply placed before the research community. It is very likely that many of these will be taken up. However, attempts to channelize or direct research efforts towards desired policy or commercial outcomes are most likely to be self-defeating. If funding for goal-directed research is easier to come by, research on truly challenging problems will suffer. Specific calls for grants of funds to research proposals addressing a defined problem invite applications from researchers who struggle to make their expertise and interest fit into the purview of the call. [1]

[1] The list of all 25 successful applicants for healthcare projects under the Nano Mission in 2017 is provided as an appendix. It includes organic chemists, electrochemists, biochemists, pharmacists, a mechanical and a textile engineer, a bioorganic chemist, a polymer chemist, a structural biologist, an enzymologist, a medical doctor, a zoologist and a physicist.

Science that investigates mechanistic probability/causality is not always necessary for technology. Although technology is necessary for scientific investigation, the reverse is not always true. Thus, a technological outcome of scientific research may or may not necessarily come about, but technological progress certainly provides better tools to engage in research. A 'base and superstructure' model may therefore be inadequate to understand the interrelationship between 'basic' science and technological 'innovation'.[2]

The pursuit of science is empowering. The primary societal benefit of scientific research is not limited to the generation of usable technology. Understanding cause and effect is crucial to the empowerment of marginalised people and is a primary purpose of scientific investigations. Not only do researchers themselves achieve empowerment, but research results that establish causality can re-claim the realm of explanation from exploitative socio-cultural power structures. Thus, science contributes to the aim of achieving social justice (Barton *et al.*, 2003). Scientific investigations inform several elements of State policy and provide for evidence-based governance. Complementarity in science and technology research can lay down ground rules to prevent hasty implementation of inappropriate technological fixes (Sarewitz and Nelson 2008).

Technology Transfer: Industry Expectations and Concerns

The present scope and extent of technology transfer from academia to the pharmaceutical industry is limited. About 8–10% of technology development projects pursued in the academia are ultimately transferred to the pharmaceutical industry. CSIR does slightly better, transferring 18% of such projects to the industry. However, 'green shoots' of entrepreneurship are now visible, wherein academia is venturing into start-ups.

Collaborative developmental research is a viable option. The majority of Indian pharmaceutical companies have strengths in process chemistry and formulations, but not in biology. It would be fruitful if biology expertise available with the academia is more accessible to the industry, particularly for drug discovery research.

Not meeting timelines is Indian academia's greatest shortcoming. The trajectory of global developments in each therapeutic area is different. For example, in oncology, if the time-to-market is greater than five years, the product under development becomes irrelevant. Similar timeframes are applicable to other areas. Decision-making protocols in the Indian, as well as global industry, are likely to terminate projects that do not meet timelines, regardless of

[2] The distinction between science and technology has been extensively debated. Whereas science addresses 'what is' and technology addresses 'what should be' (see: Skolimowski H. The structure of thinking in technology. Technol. Culture 1966; 7:371-83), the areas of interest of these two fields are apparently divergent. The distinction between technology and craft is based on the theoretical underpinning of technology as opposed to the skill/creativity required for craftsmanship. Two kinds of theories are postulated for technology-- 'substantive theories' or 'knowledge that (e.g., x always happens)' and 'operative theories' or 'knowledge how (x) can be made to happen)'—see: Bunge M. Technology as Applied Science. Technol. Culture 1966; 7:329-47; and: the Stanford Encyclopaedia of Philosophy https://plato.stanford.edu/entries/knowledge-how/ (accessed 29 Nov 2017).

innovative merit (Jekunen 2014). Further, financial costs of research expand to unviable levels if deadlines are not met, compromising returns on investment. Therefore, it is best if academia does all the 'homework' before approaching the industry for collaborative product development.

The mobility of personnel in companies is a significant hurdle in sustaining collaborations. Collaboration requires building rapport. Also, new incumbents tend to view their predecessor's effort with greater scepticism. Institutional mechanisms are not in place within the industry to nurture long-term collaborations. Personnel mobility also adversely affects adherence to timelines.

The Indian academia is largely unfamiliar with the regulatory landscape. While it may be acknowledged that drug regulation tends to verge on the absurd, the Industry has no choice but to work within the regulatory framework. Thus, data generated in facilities that do not have accreditation by agencies recognized by the Drug Controller General of India [DCG(I)] is very often not appropriate for the purpose of seeking permissions for clinical trials or for product registration. If they are serious about technology transfer, academics must read and understand the regulations governing drugs, biologicals, devices, phytopharmaceuticals, AYUSH products etc., as applicable. Data integrity and reproducibility of results must be ensured.

Clinicians have to be engaged with in detail. Clinicians are even less interfaced with industry than are academic researchers, and bridges must be built. Extensive consultation among several clinicians, academics and industry-based colleagues will not only strengthen the therapeutic rationale of a discovery product, it can also open up newer areas of research and product development.

Public-funded drug discovery and development research on low-profit market segments should build links with pharmaceutical public sector units. Large sections of the society and public health needs of the country require medicines that are not sufficiently profitable to sustain private sector companies. A win-win situation can be engineered, wherein PPSUs can derive benefits from cost reduction, import substitution, therapeutic value enhancement, etc., as the outcome of academic research. Affordability as a policy should be a priority for drug research.

The industry-academia relationship is fraught with misunderstandings. During the discussions, as well as on the sidelines, the misconceptions prevalent among academia and industry-based colleagues became apparent. Some of these are listed with the objective of flagging issues that need to be addressed for the 'trust deficit' to be overcome.

Academic Researchers' Misconceptions About the Indian Pharmaceutical Industry

1. *The industry has a lot of money to invest, so we should try to maximize upfront earnings from technology transfer*. This is not true. The industry is not monolithic. Start-ups, MSME and generics companies are certainly not flush with funds. Even bigger firms have meagre allocations and stringent accounting for research budgets.

2. *The industry will have no compunction in stealing my idea*. While it is prudent to secure IP, academics must weigh the consequences of patenting early and thereby foregoing the advantage of a longer period of exclusivity. Most often, the industry-based colleague will have no time (or inclination) to work on your idea, much less possess the resources (*see above*) to be able to take it to fruition. Confidential disclosure agreements are sufficient for the protection of data exclusivity.

3. *The industry has no appetite for taking risks, has no interest in the science behind my research, and is only interested in making profits*. (*see #1 above)*. Making money is not a bad thing, or a questionable motivation for drug discovery and development. The industry will take only as much risk as its R&D budget can afford. The level of validation (of the scalability of the manufacturing process, the quality of evidence of safety and efficacy, etc.) is the major determinant of whether or not a risk is worth taking.

4. *The industry does not have sufficient competence to implement/execute my idea*. Most companies have limited portfolios. If a company has a product that is even remotely similar to your target product profile, no concern about competence is valid.

Industry-based Colleagues' Misconceptions About the Indian Academia

1. *Academics are only interested in publishing papers and going abroad to international conferences*; *they are ignorant about the industry and have contempt for it*. If there are such people, they'd better be left alone—and would have never approach the industry for collaboration! An overture to the industry recorded from an academic is an expression of good faith.

2. *Academics don't know how to convert an idea into a product*. A considerable (and rising) number of successful academic-entrepreneurs contradicts this view.

3. *Academics are unwilling to align with the objectives of the industry*. Academics are unwilling to engage in work that offers no intellectual challenge.

4. *Academics don't know when to stop a research program.* But they are perfectly willing to stop a product development program if it appears infeasible. The pursuit of curiosity-driven research need not bother the industry.

Funding and Costing for Collaborative Drug Discovery and Development

The cost of drug discovery is difficult to estimate. US$ 250M is a figure accepted widely among investors. However, different estimates vary 9-fold or more (Morgan *et al.,* 2011). A figure of $2.6B has been cited in the popular press in mid-2017. The cost of discovering and developing Centchroman (ormeloxifene) entirely through public sector funding is not recorded.[3] Cost estimates of drug discovery in the Indian private sector follow the global trend of factoring in costs of all failures during the relevant discovery/development life cycle. ?

Disbursal of public funds to the pharmaceutical industry has evolved over the years to the de-risk industry. The public-private-partnership (PPP) mode of collaboration has developed from a 'loan'- based model in 1993 to grant-in-aid mechanism today, through the efforts of CSIR (DPRP, NMITLI, etc.) and DBT/BIRAC programmes. However, an optimal level or proportion of public funding for private enterprise is yet to be established.

Public and philanthropic funding for drug discovery and development is well-developed in Europe, USA, etc., but is not adequate to meet full costs. The Innovative Medicines Initiative has budgeted €3.3B for 2014–2024.[4] This works on a PPP model. Calls are initiated when a consortium of EFPIA companies is formed. The Karolinska Institute is a major beneficiary.[5] The external funding of the MIT in 2016 was $428.1M and the total expenditure on consumables was 3350M. Non-government funds typically contributed barely 28%.[6] This is vis-à-vis a public-funded institution that has the strongest IP portfolio in the world.

The measurable output of public-funded drug research is meagre worldwide. Notwithstanding the Bayh-Dole Act[7] (Markel 2013) in the USA, 153 new FDA-approved drugs, vaccines, or new indications for existing drugs were discovered between 1971–2011 through research carried out in public-funded institutions. These are 93 small-molecule drugs, 36 biologic agents, 15 vaccines, 8 *in vivo* diagnostic materials, and 1 OTC (Stevens *et al.* 2011). However, the US FDA's Orange Book has very few entries where public-funded institutions such as MIT or

[3] Although an estimate for the cost of developing α/β-arteether is available at https://thewire.in/author/amisra/ (accessed 26 September 2017); and is likely to be between 4.5-9 crores in real terms.
[4] http://www.imi.europa.eu/ (accessed 29 Nov. 2017).
[5] http://ki.se/en/staff/innovative-medicines-initiative-imi (Accessed 29 Nov. 2017)
[6] http://web.mit.edu/facts/financial.html (Accessed 29 Nov. 2017)

Johns Hopkins are the applicants. In the 40-year period, USFDA granted a total of 1541 approvals, of which 143 (<10%) were applied for by institutions themselves. Since the USA does not have any mechanism of public-sector pharmaceutical manufacturing, their model is simply to create a vehicle for the transfer of IP generated by public funds to the private sector. In contrast, Brazil and many Latin American countries, Russia and Eastern European/Central Asian countries, India, China, Indonesia, Sri Lanka, Nepal, etc., have a 'mixed economy,' where pharmaceutical manufacturing has both private and public sector players. In Cuba, for instance, government produces drugs and vaccines that cover 80–90% of the market.[8] Russia, wherein 100% of pharmaceutical production was once government-owned, has progressively diluted government shareholding after the collapse of the Soviet Union. However, Russia now recognizes that relinquishing government ownership of the means of production of medicines has strategically weakened the country, and its 2020 Policy Objectives aim at import substitution and self-reliance. China has a pharmaceutical manufacturing and pharmaceutical/ biotechnology R&D sector that is >70% government-owned.

Venture Capital (VC) and Angel Investor funds for drug discovery and development are difficult to come by. VC firms are funding hospitals, pharmacy chains and e-pharmacy, not research. Short-termism is generally encountered, and VC gets frustrated if there is no exit after even 10–12 years of a drug discovery programme have elapsed. VC firms do not have an objective framework of conducting due diligence; they instead rely on personal knowledge and peer networks to assess drug research programmes to invest in. Prediction of returns on investment in India for drug discovery and development is not easy. Unpredictability is due to the IP regime and its enforcement, and the therapeutic trajectory of disease areas (e.g., warfarin was out of the market within 10–15 years). It is likely that VC firms will invest in high-technology/ high-cost areas such as biosimilars and RNA interference therapeutics, but small molecule drugs are not on the radar.

The Indian pharmaceutical industry cannot be expected to fund drug discovery and development research. Profit margins may be high, but budget allocations for meaningful R&D are meagre. A drug pricing regimen is in force in India. Exports are declining. The dominant business model is to provide a cheap manufacturing base for multinational pharmaceutical marketing firms. This results in the core competence of the pharmaceutical industry moving decisively to provide manufacturing services for technology that is ready to deploy, rather than investing in technology development.

PPP model of funding deserves a second look and a bold step should be taken to deploy public funds for better outcomes. Since 1993 to date, the industry has been reluctant in setting up plants for manufacturing active pharmaceutical ingredients (API), even if government funds

[7] The University and Small Business Patent Procedures (Bayh-Dole) Act of 1980. Public Law 96–517, 96th Congress. December 12, 1980. 94 Stat. 3015.

[8] http://www.businesswire.com/news/home/20150924005659/en/Research-Markets-Cuba-Pharmaceutical-Market-Report-2015-2018. This is especially ironic for India, since the first ever pharmaceutical plant in Cuba was set up with help from Sarabhai Chemicals, an Indian private sector company. Cuba returned the favour by helping set up Hindustan Antibiotics Ltd. Today, the Cuban QUIMEFA constituents source most of their discovery research from Cuban public-funded institutes. Heber Biotec SA have even transferred technology to, for instance, Panacea Biotech.

and incentives are made available. More than 95% of start-ups in the pharmaceutical sector that were funded by government are inviable. India is now insecure in terms of manufacturing key starting materials, intermediates and API. This state of affairs must also be viewed in the context of India-China relations. The oldest VC firm in India continues to have the Technology Development Board as an investor (~₹30 crores). Therefore, a re-look is required before the policy of prioritising funding for PPP collaborations is continued to be carried forward.

Policy objectives of drug affordability and access require investments in public-funded drug research. Prices of medicines can be controlled, kept in check, and most often significantly reduced if there is a market competition without a violation of our WTO obligations regarding TRIPS. The second goal is to ensure access to essential medicines. In a drug prices control regime, where the National Pharmaceutical Pricing Authority (NPPA) caps the prices of drugs on the National List of Essential Medicines (NLEM), it becomes necessary to offer the private sector blandishments such as subsidies, tax breaks, duty exemption, utilities, services, assured or captive markets — in short, all the negatives that are associated with public sector manufacturers; just to ensure that supplies are available. The WHO summarized arguments for and against public-sector manufacturing of pharmaceuticals by 1997 (Bennett *et al.*, 1997). In retrospect, their analysis and projections were not borne out of events. WHO had not considered pharmaco-economics models of lot-discretization as a means of reducing cost and insisted that economies of scale are the sole means of doing so. The rise of IT-enabled demand aggregation and inventory control mechanisms were not considered. Lastly, they did not factor in the role of incorporating public-sector research outputs into public sector production.

The notion of a self-sufficient public sector is erroneous. The Indian pharmaceutical industry has progressively reduced its investment in new drug discovery because the return on investment is not sufficient despite high profit margins. Suppose a public-funded institution like CSIR-CDRI licenses a drug that has an annual sales of ~100 million USD (equivalent to INR 6500000000) it typically gets 2% (INR 13 crores) as royalty. To earn its annual budget entirely from royalty, 10 blockbusters drugs must be launched every year from CSIR-CDRI—something that no entity in the world is capable of achieving. Public institutions should address issues that are societally useful and are not addressed by the private sector. India is now API-insecure, and this must be viewed in the context of India-China relations. India has ignored public sector manufacturing of APIs to its own strategic peril. This has been realised, and it is now rumoured that Niti Ayog has recommended setting up Mega Pharma Parks with an outlay of 5000 crores of public money, on the lines of SEZ. It is incomprehensible why green fielding an SEZ is a better option compared to investing a tenth of the capital on existing Pharma PSUs. Thus, to argue that public sector drug research and drug manufacturing should be self-sustaining even as it addresses the needs of affordability, access and novelty — while private enterprise should receive subsidy — is perverse.

During peer review of this manuscript, it was suggested, among other things, that we should “flag disagreements and the bases thereof that arose during the conclave regarding the general propositions” to “make the subsequent conversations more substantive.” As pointed out in the Introduction, we have reported general propositions without attribution to a specific panellist, or the discussants on the floor of the house, or in the sidelines. This was a conscious

decision, as we believe that anonymity is conducive to wider dissemination of views. We, therefore, submit that attempts on our part to identify disagreement (rather than consensus), while certainly helping to focus on the debate between two clearly identifiable entities, do not serve our purpose. We instead hope that this reportage has successfully highlighted the shades of informed opinion spread across a spectrum of diversity — regardless of the formal affiliation of an individual: to the pharmaceutical industry, the academia, the administrative or the funding bodies. And that, indeed is an extremely encouraging sign that this debate will be productive.

Acknowledgments

This is CSIR-CDRI Communication Number 9605.

Appendix 1

List of successful nanomission projects funded by DST in 2017

Sr. No.	Date of Sanction	DST Reference Number and Project Title	Principal Investigator details
1	03.05.2016	SR/NM/NS-1252//2013 Regulatory pathways and role of zinc oxide(ZnO) nanoparticles in angiogenesis	Chemist Department of Biomaterials Indian Institute of Chemical Technology Hyderabad 500 007
2	23.05.2016	SR/NM/NS-1376/2014 Carbon Nanotubes Based Electrochemical Immunosensor for small Cell Lung Cancer Diagnosis	Electrochemist (studied at Ruhr Universität Bochum) Indian Institute of Technology Ropar 140 001(Punjab)
3	30.05.2016	SR/NM/NS-01/2015 Fabrication and characterization of hybrid nano sponge dressing for healing of infections burn wound	Biochemist Department of Biotechnology Mepco Schleck Engineering College Sivakasi 626 005(Tamil Nadu)

4	05.07.2016	SR/NM/NS-1118/2014 Brain targeting of an anti-epileptic drug via intra-nasal nanostructured lipid carriers	Pharmacist Department of Pharmaceutics Amrita School of Pharmacy Health Science Campus, AIMS Ponekkara, Kochi 682041 (Kerala)
5	13.07.2016	SR/NM/NS-1141/2015 Multifunctional Magnetic Nanoparticles for Cancer Theranostic Applications	Engineer Department of Mechanical Engineering Shiv Nadar University Noida 201 314 (Uttar Pradesh)
6	13.07.2016	SR/NM/NS-1118/2015 Engineering of Self-assembled lapidated nanoparticles for cancer combination therapy	Bioorganic Chemist Regional Centre for Biotechnology 3rd Milestone Faridabad-Gurgaon Expressway, Village Bhankri Faridabad 121 001(Haryana)
7	20.07.2016	SR/NM/NS-1004/2015 Hybrid Magnetic Nanoparticle Aptamer Bio-sensor for On-Farm Early Pregnancy Diagnosis in Cattle	Veterinary Virologist Translational Research Platform for Veterinary Biological and Animal Biotechnology, Tamil Nadu Veterinary and Animal Sciences University, Chennai
8	03.08.2016	SR/NM/NS-1111/2015 Evaluating therapeutic potential of polyglutamine aggregation peptide inhibitors through nanoparticles-based-delivery approach in Huntington's disease	Structural Biologist Department of Biological Sciences and Bioengineering Indian Institute of Technology-Kanpur, Kanpur 208 016
9	09.08.2016	SR/NM/NS-1470/2014 Synthesis and characterization of siRNA loaded ligand bearing PLGA nanoparticles for targeted delivery to the lung cancer	Biochemist (CDRI) Centre for Biotechnology University of Allahabad Allahabad 211 002(Uttar Pradesh)

10	06.09.2016	SR/NM/NS-1091/2015 Development of biodegradable nanoparticles for concomitant delivery of anti-cancer peptide/DNA and chemotherapeutic drugs for cancer therapy	Polymer Chemist Centre for Biomedical Engineering Indian Institute of Technology New Delhi 110 016
11	15.09.2016	SR/NM/NS-1135/2015 Development of nanofibrous membrane for wound healing by controlled release of Indian honey and curcumin	Textile Engineer Centre of Excellence for Medical Textiles South India Textile Research Association (SITRA), Tamil Nadu, Coimbatore 641 014
12	25.11.2016	SR/NM/NS-1154/2015 Delivery of miRNA-nanoparticle complex to promote repair and regeneration after myocardial injury	Pharmacist Centre for Nano bioscience Agharkar Research Institute GG Agharkar Road, Pune, Maharashtra 411 004
13	16.12.2016	SR/NM/NS-1183/2015 Development of lipophilic gadolinium chelates conjugated silica and titanium dioxide nanoparticles as contrast enhancing agents for magnetic resonance angiography	Chemist Department of Chemistry Loyola College, Nungambakkam, Chennai, Tamil Nadu 600 034
14	04.01.2017	SR/NM/NS-1475/2014 Molecular structure and supramolecular packing of misfolded proteins within the amyloid nanostructures: A Nanoscale Biophysics Approach	Organic Chemist Chemical Sciences & Biological Sciences Indian Institute of Science Education and Research (IISER) Sector-81, S. A. S. Nagar, P.O. Manauli, Mohali 1403 06 (Punjab)
15	05.01.2017	SR/NM/NS-1510/2014 Low cost diagnostic system for public health surveillance targets bacterial enteric pathogens	Electrochemist/Material Scientist Department of Nanotechnology Institute of Nano Science and Technology, Habitat Centre, Phase-10, Sector-64 Mohali 160 062 (Punjab)

16	06.01.2017	SR/NM/NS-1017/2016 Hepatocyte Targeted Carbohydrate Anchored Smart Nanostuctured Lipid Carries for treatment of Malaria	Pharmacist Department of Pharmaceutics Bombay College of Pharamacy Kalian, Santacruz(East) Mumbai 400 098
17	13.01.2017	SR/NM/NS-1027/2016 Evaluation of the potential of siRNA loaded lactoferrin nanoparticles for the treatment of prostate and testicular cancer	Zoologist Animal Biology University of Hyderabad P.O. Central University Hyderabad, Telangana 500 046
18	17.01.2017	SR/NM/NS-1185/2015 A Therapeutic approach of targeted delivery of miRNAs through nanoparticles to control metastasis of Triple Negative Breast cancer in-vitro and in-vitro and in-vivo	Cell Biologist (Signalling) DST INSPIRE FACULTY Centre for Research in Nanoscience and Nanotechnology University of Kolkata Kolkata, West Bengal 700 098
19		SR/NM/NS-57/2016	Medical Doctor Department of Medicine Institute of Medical Science Banaras Hindu University Varanasi 221 005
20		SR/NM/NS-57/2016	Biochemist Department of Biochemistry Institute of Medical Science Banaras Hindu University Varanasi 221 005
21	23.01.2017	SR/NM/NS-16/2015 Exploring the synergism of PPAR-Y agonist and HDAC inhibitor for reversal of Alzheimer's type of dementia and developing their brain targeted nano-carrier system for effective treatment	Physicist Department of Physics Birla Institute of Technology and Science, Pilani, Rajasthan 333 031

22	25.01.2017	SR/NM/NS-1205/2015 Multifunctional stimuli responsive theranostic magnetic nano micelles for treatment of breast cancer	Biochemist Center for Nanotechnology & Advanced Biomaterials, School of Chemicals & Biotechnology, SASTRA University, Thanjavur, Tamil Nadu 613 401
23	20.02.2017	SR/NM/NS-1185/2016 Candidate chikungunya virus vaccine: nanoparticle-mediated delivery of recombinant antigens to antigen presenting cells (APCs)	Molecular Virologist Center for Nanobioscience Agharkar Research Institute G.G. Agharkar Road, Pune 411 004
24	06.03.2017	SR/NM/NS-1113/2016 Supramolecular assembly of glycol-nanoparticles to target endothelial inflammation in brain	Chemist Department of Chemistry Indian Institute of Science Education & Research (IISER) Dr. Homi Bhabha Road, Pashan, Pune 411 008 (Maharashtra)
25	20.03.2017	SR/NM/NS-1099/2016 Targeting onco-miRNAs with a novel oleic acid-pluronic stabilized porousTiO2 nanoparticle for specific synergistic delivery of small molecule combination to combat triple negative breast cancer	Enzymologist Department of Molecular Medicine; Bose Institute, P1/12 CIT Scheme VIIM, Kolkata, West Bengal 700 054

References

1. Barton, A. C., J. L. Ermer, *et al.* (2003). *Teaching Science for Social Justice*. New York, Teachers College Press, Columbia University.
2. Bennett, S., J. D. Quick, *et al.* (1997). Public-Private Roles in the Pharmaceutical Sector: Implications for equitable access and rational drug use. Geneva, World Health Organization.
3. Endo, A. (1992). "The discovery and development of HMG-CoA reductase inhibitors." *J. Lipid Res.* **33**(11): 1569-1582.
4. Jekunen, A. (2014). Decision-Making in Product Portfolios of Pharmaceutical Research and Development – Managing Streams of Innovation in Highly Regulated Markets. *Drug Design, Development and Therapy* **8**: 2009–2016.
5. Lauterbur, P. C. (1989). Image formation by induced local interactions. Examples employing nuclear magnetic resonance. 1973. *Clin. Orthop. Relat. Res.*(244): 3-6.
6. Markel, H. (2013). Patents, profits, and the American people--the Bayh-Dole Act of 1980. *N. Engl. J. Med.* **369**(9): 794-796.
7. Marsh, N. and A. Marsh (2000). A short history of nitroglycerine and nitric oxide in pharmacology and physiology. *Clin. Exp. Pharmacol. Physiol.* **27**(4): 313-319.
8. Morgan, S., P. Grootendorst, et al. (2011). The cost of drug development: a systematic review. *Health Policy* **100**(1): 4-17.
9. Sarewitz, D. and R. Nelson (2008). Three rules for technological fixes. *Nature* **456**(7224): 871-872.
10. Stevens, A. J., J. J. Jensen, et al. (2011). The role of public-sector research in the discovery of drugs and vaccines. *N. Engl. J. Med.* **364**(6): 535-541.
11. Tobert, J. A. (2003). Lovastatin and beyond: the history of the HMG-CoA reductase inhibitors. *Nat. Rev. Drug Discov.* **2**(7): 517-526.
12. Wahi, V., N. K. Ganguly, et al. (1989). "Enzyme immunoassay (ELISA) for the detection of anticarbohydrate antibodies in rheumatic fever and rheumatic heart disease." *Jpn. J. Exp. Med.* **59**(4): 163-166.