The Tip of the Iceberg: The Quest for Innovation at the Base of the Pyramid

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Abstract Much of the world in Asia, Latin America, and Africa is at an early stage of economic development similar to what the United States and other developed countries experienced many decades ago. Yet, much as their needs for hard and soft infrastructure, effective business practices, and an educated workforce parallel similar needs that underlay earlier development in the West, replicating Western development would overlook the hallmarks of the current century: widely available information and communications technology; a set of electronic linkages among the world; and a global business environment, to name just a few. Consequently, it should be possible to allow developing countries to use "leapfrog" technologies that were inconceivable decades ago to support their development. One means of identifying these opportunities is by matching traditional development needs with novel support by connecting previously unrelated literatures.

Equally interesting, the poor in many regions are compelled to seek innovative solutions that extend their resources and otherwise make their lives easier. These can include truly surprising hybrids (like washing machine – bicycles) that serve distinct local needs. Yet, these innovations have the potential to be of great value in West, either through direct commercialization or serving as a source of inspiration. These developing world innovations, too, can be linked to currently unrecognized needs or opportunities in the West by proper cross-fertilization. Again, literature-based methods may be an effective means to discover mutual benefits linking the developing and developed worlds.

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1 The Base of the Pyramid and Innovation

The economic base (or bottom) of the pyramid represents the two to five billion people living lives at or barely above the poverty level. The description comes from imagining the world's population divided into strata according to personal income, and then layering these strata one upon the other, the lowest income at the bottom. The resulting shape would be something like a pyramid, with vast numbers of the world's population living at its base. As Prahalad and Hart [28] point out in their article, "The Fortune at the Bottom of the Pyramid," approximately four billion of the six billion people on the planet live on $4 a day or less (calculated in terms of PPP, purchasing power parity, meaning what $4 would buy in the U.S.). Of these, several billion live on less than $2 or even $1 per day. An additional 1.5 to nearly 2 billion people live on incomes above $4 daily, but still less than $20,000 annually. Finally, there are a few hundred million people living on annual incomes above $20,000. The bulk of the very poor live in India (population, 1.1 billion), China (1.3 billion), and Africa/Latin America & Caribbean (0.85 billion).

The problems facing the poor are those that too naturally flow from living on such low incomes. Health problems are magnified because of inadequate healthcare facilities or the poor's inability to afford the healthcare that is available. These medical problems include many preventable and treatable diseases, such as malaria, a debilitating and often deadly affliction for millions. Similarly, sanitation and housing are normally not of a standard to support a healthy life. Lack of adequate educational opportunities are among the other deficits the poor encounter.

Many approaches have been suggested for providing better economic opportunity for those with such little means[1]. For over a half century, governments in the developed world and institutions such as The World Bank, International Monetary Fund, and other multilateral institutions and charities have offered financial and other support. Despite the failure of these efforts to eliminate or even deeply dent poverty, ambitious new efforts for directing and administering aid have been offered. The Millennium Villages Project in Africa, championed by Jeffrey Sachs, aims to provide an integrated set of scientific and economic remedies to lift people out of poverty [23]. Lodge and Wilson [22] propose the establishment of a permanent partnership among key MNCs, aid agencies, and NGOs to help define a series of economic and development projects and the right actors to carry them out in specific parts of the world [22].

An approach that has captured the public imagination is using the capabilities of business to sell to and build businesses supporting job and business creation at the bottom of the pyramid ([28]; Prahalad 2005; Hart 2005). In aggregate the wealth of the poor is staggering, because of their sheer numbers. And they are a source of energetic, innovative energy, if only it can be tapped. As Prahalad opens his book:

[1] No one has suggested using the literature based discovery techniques for assistance. Showing how this may be done is at the heart of this paper.

> If we stop thinking of the poor as victims or as a burden and start recognizing them as resilient and creative entrepreneurs and value-conscious consumers, a whole new world of opportunity will open up. Four billion poor can be the engine of the next round of global trade and prosperity… [and] a source of innovations.

A key point in Prahalad's thinking is occasionally overlooked or misstated. He believes that a business ecosystem, with multinational companies playing a central "nodal" role, will help unleash the entrepreneurial spirit of the poor. They will sense the opportunity to provide and improve products or services, and with an infrastructure in place, will take advantage of the opportunity and do so.

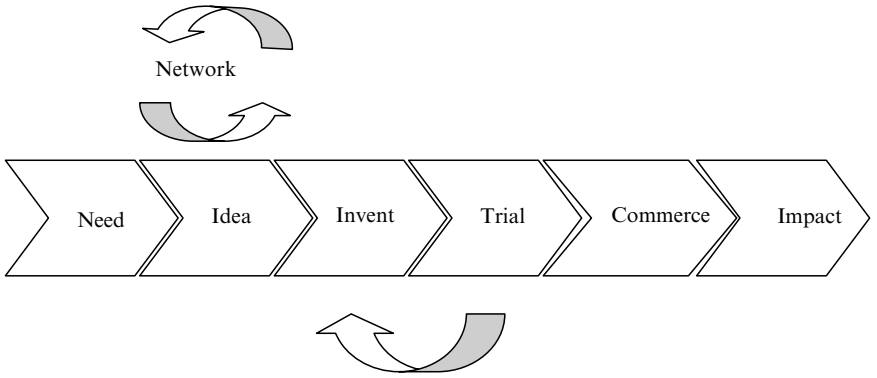
A stronger version of these sentiments is offered by Professor Anil Gupta, of the Indian Institute of Management, Ahmedabad. The rural poor represent the "tip of the (economic) iceberg": what you see hides what lies beneath – enormous potential to produce, a tremendous storehouse of innovation and creativity. Why? Simply because the poor understand their needs and have found innovative ways to meet them with the limited resources at their disposal. One of the definitions of innovation captures the essence of why the poor offer tremendous innovation potential: "(Innovation is) a mindset, a pervasive attitude, or a way of thinking focused beyond the present into the future" [20].

Gupta has established social systems for scouring the rural countryside to identify individuals with innovative, generative capacity. By means of these shodh yatras, or journeys of discovery, he has identified tens of thousands of rural innovations and applications of indigenous knowledge. Innovations range in size, scope, application, and degree of sophistication. Many involve applications of local knowledge for veterinary or human purposes, crop protection etc. Others involve technologies for heating, refrigeration, communication, and farming.

Interestingly, the bulk of innovation occurs in one specific rural area of India, the state of Gujarat. With limited local assets and access to external resources (finance, technology, information), rural communities face significant livelihood challenges. Communities derive goods and services from five types of assets: (1) natural, (2) social, (3) human, (4) physical, and (5) financial [7]. In rural communities, due to a shortage of other assets, the key resource available for the poor is social capital; communities must work together for the sake of their livelihood [11, 12, 19, 30, 37]. In vulnerable and marginal communities, the need for innovation is imperative [8]. The locus of rural innovation in India, therefore, occurs in an area where significant social capital has been developed, both within the community and, to a degree, with the surrounding business community that represents outside innovations. A handful of products have been patented, beginning their climb from local to potentially broader application, with the resulting possibilities of generating income for their inventor and local job creation as well. A small number of institutions in India developed by Gupta and others support the conversion of innovation into marketable product.

A stylized flow diagram captures some of the necessary transformations that must occur for an innovation to reach its potential impact. The flow diagram is aligned with source-based stage models of innovation that flow from idea inception

to final product, with the person who initiates the new idea, the innovator, being the source [1, 17, 36, 40]. Based on a legitimate local need, an idea arises to address it. (Indeed a network of innovators may incorporate suggestions from each other, adopt each others' ideas, and otherwise support each other, therefore utilizing their social capital.) At the stage of invention, the right (local resources) must be obtained along, possibly, with necessary tooling to produce a series of ever-refined, ever-informative prototypes. In certain innovations, such as using Teflon coatings for clay pots, experiments may rapidly determine the best course of action (the best means of application of liquid Teflon and the amount to apply). More complicated innovations may require months or years of experimentation and many widely varying product designs. Naturally, user trials and acceptance and other forms of technical feedback are fed into the prototyping process. Once ready for use, the innovation faces the challenges of the market. These certainly include but are not limited to considerations such as manufacturing, distribution, marketing, etc. Legal, policy, and other societal considerations may also be key in assuring commercial success.



Innovations based on using local plants for medicinal or other beneficial means is a bit different. There have long been local uses for plants and herbs. But skepticism, secrecy, and indifference have sometimes caused the usage of extremely effective plants and herbs to be overlooked as a means of providing benefits to large numbers of people. For instance, one of the drugs currently part of the modern armamentarium for combatting malaria is artemisinin. The Chinese have used sweet wormwood (artemisia annua L.), from which artemisinin is extracted, for at least a century for its medicinal uses (including to combat malaria the last several decades). Ninety percent effective in combination with other drugs, and endorsed by the World Trade Organization, the beneficial effects of wormwood escaped the attention of the West until recently. Now, intensive efforts are under way to produce and extract sufficient quantities using modern practices to provide artemisinin based therapy widely. Such a flow of awareness is aligned with user-based stage models of innovation, which are based on the perspective of the user, rather than the innovator, and follow the

innovation process from the user's awareness to the incorporation of the innovation into the user's behavioral routines [3,25,36,39]. Increasingly, local innovations from rural communities are being acknowledged by a global set of users. Traditional (indigenous) knowledge is being recognized for an increasing number of uses in addition to human and animal healthcare. Among them are: supporting pest control, crop diversity, soil conservation, and water management.

In the cases of both the invention of physical goods at the base of the pyramid (mechanical devices, electronic devices, etc.) and the application of indigenous knowledge, there is great potential for finding broader acceptance or even new applications. One possible means for doing so is through connections to companies and organizations in the West. A Western business, for instance, can provide support at any stage of the value chain. Conversely, the new ideas flowing from the innovators may provide opportunities for the Western companies to fulfill unanswered needs of their customers, or to develop novel offerings based on inspiration from rural innovators. A resulting innovation may consequently be improved in terms of the features it contains, the materials it uses, or its manufacturability. The resulting price: performance ratios can be dramatically altered, as in these cases in India: making and fitting of prosthetic limbs and performing eye and heart surgeries, where the cost advantages are 40, 50, and 200 *times*, respectively. For performance comparable to the highest Western standards. Western firms can be instrumental in helping translate these advantages to broad markets, worldwide.

We can begin to understand the possible mutual benefits of Indian innovators working with Western institutions by looking at how innovations may fail to become widely adopted commercially. An innovation that truly meets a local need may suffer in its journey towards commercial application at different stages. Funding, technical expertise, or certain design principles may be lacking during the creation of a series of prototypes. Initial trials may be thwarted by the lack of funds or other resources for manufacturing, distributing, or testing. Trials may indicate the need for product enhancements, for which additional resources are required but lacking. Successful local trials that indicate market acceptance benefit from expertise in and possible partnerships in sales, marketing, distribution, licensing, and securing appropriate intellectual property rights (an issue that is especially crucial where local, indigenous knowledge may be threatened by outside commercial interests). Again, resources in the form of capital, knowledge, and overall support for business execution will all be required for an innovation to gain significant traction.

Using networks of resources to foster the innovation process has been discussed in various literatures, including: innovation [13,31], sociology of science [21], and sociology of economic institutions [26]. Networks facilitate the ability to transmit and learn new knowledge and skills [26]. Accordingly, innovation is increasingly fostered through networks of learning that involve various entities and organizations [27]. One such example of a successful network of innovation is open-source software development [5,41]. However, developing a network does not relieve the need for the local innovation participants to be capable and innovative, nor does it eliminate the importance of Western institutions providing necessary resources for

execution. Rather, it merges the two [2,24]. We examine several innovation networks in the context of the base of the pyramid and literature-based discovery towards the end of the paper.

2 Disruptive Technologies

In the mid twentieth century, Schumpeter [32] coined the phrased "creative destruction." With parallels to biological adaptation, creative destruction seeks ever better adapted forms of business and industry, at once creating new value but destroying incumbent firms and industries. Firms seeking to grow their markets can be trapped by the expectations of the their customers, their own relentless drive to improve their existing products (though in incremental ways), and management and accounting systems that are ill-suited to establishing and funding market-place experiments. Small, hungry firms, on the other hand, can much more easily introduce products that people in the developing world would hunger for but that would accurately be perceived as sub-standard in the developed world. For instance, Christensen and Hart [9] and Christensen et al. [10] talk about extremely low cost ($3,000) mini-vehicles in China (GM participated in this joint venture) and other "disruptive technologies" like stripped down microwaves. These, though, still fail to address markets at the true bottom of the pyramid. In contrast, disruptive communications technologies like n-Logue's wireless, broadband (in India); Grameen's (Bangladesh) disruptive service model for providing cellular service; and solar photovoltaic, wind, fuel-cell, and micro-turbine power generation (across the developing world) currently provide solutions to the real problems and needs of the poorest of the poor. It is easy to understand that these technologies *only* address the needs of the poor. Who in the West, for instance, wants intermittent, relatively expensive, limited electrical power? Yet, as such technology takes root in the developing world – where it is truly welcome since it far surpasses alternatives on these dimensions – its quality, performance, and price will all improve. Such perfected disruptions make them formidable candidates for moving cross- or up-market to compete with long-entrenched technologies that can begin to appear outdated.

Writing in *Seeing Differently: Insights on Innovation*, Bower and Christensen [4] summarize the qualities of disruptive innovations. The technologies do *not* meet current Western needs along one or several important performance dimensions. But, over a relatively short period of time, as they are widely trialed and adopted, they will dramatically improve to the point where they can successfully invade mature, existing markets. For Western firms not to be caught off guard and miss out on these advances, they advise them to avoid their traditional channels in gauging these new markets and, rather, to let other, nimbler organizations conduct experiments but to monitor them closely.

The development of disruptive technologies is supported by the trend towards democratizing [41] and distributing innovation. Web sites such as digitaldividen.org, nextbillion.net, and thinkcylce.com foster open access and collaboration directed at innovation. Such communities are sponsored by non-profits, academic institutions,

and for-profits. Each uses information-technology to support social connectedness, collaboration, and innovation across various communities, including those communities that are underserved. We suggest supporting these innovation communities in a new way through literature-based discovery.

3 Application of Literature Based Discovery

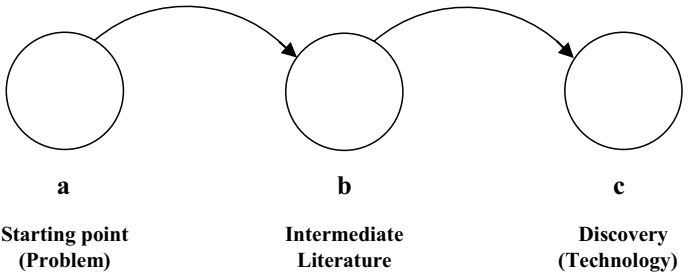
With proper linkages, the ingenuity, creativity, and resourcefulness of rural innovators can be joined with the business, financial, and engineering muscle of the West. Both sides can benefit. Though other means of forging such linkages are, of course, possible, we suggest that literature based discovery may play a productive role in forging them.

A few years ago, Gordon et al. [15] discussed several modifications to literature based discovery as it is currently practiced. To begin with we suggested that literatures other than MEDLINE were appropriate starting points, the advantages of the uniformity and careful indexing of MEDLINE notwithstanding. The same (over-) specialization that makes it difficult to connect ideas within medicine suggests that there are missed connections and missed opportunities in other areas of application. These likely occur far more often than we suspect, primarily because it is hard to know what you're not seeing when you're not seeing it. Historically, the widespread adoption and uses of the telephone, movie projector, mainframe computer, and the Internet were all overlooked or missed entirely by individuals and companies that should have been in position to know. For example, in the biomedical arena, Richard DiMarchi, Vice President for Endocrine Research at Eli Lilly and Company, emphasized that the biggest mistake his company could make in managing research alliances was to treat them as "one-offs" – independent relationships pursued separately [27] – rather than see the continuing potential for innovation.

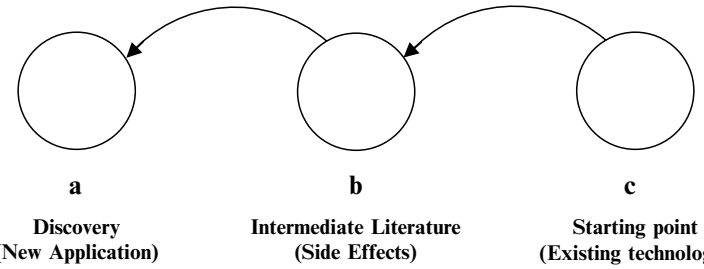
Gordon et al. went on to suggest that the "direction" of literature-based discovery could be turned around. Vos [42] argued that drugs produce a set of effects, some wanted and others initially viewed as negative "side effects." Yet, these side effects can produce blockbuster drugs. The drug minoxidil, developed for hypertension, became the baldness drug Rogaine. Sildenafil citrate was an unpromising drug for alleviating chest pains that has had far more success as Viagra. Weeber et al. [43] proposed a literature based discovery support architecture based on Swanson's [34] pioneering efforts that could be used for matching the "side effects" of drugs with conditions where these effects would be wanted.

We suggested inverting the disease-cure trajectory that Swanson had initially proposed and applying it to find new applications for technology in any discipline, not just medicine. In a series of experiments on the World Wide Web, we demonstrated how what we called *extension* was possible in the area of computer science. The figures below (adapted from Gordon et al. (2002)) show the flow of "traditional" literature based discovery and extension, respectively. It is interesting to note that "traditional" literature based discovery is aligned with source-based models of

innovation, which start with an innovator addressing a problem. Literature-based discovery using extension corresponds with user-based models of innovation, which start with user awareness of a new application or innovation.



Flow of Traditional Literature-Based Discovery



Flow of Extension in Literature-Based Discovery

We made two other observations in Gordon et al. [15] that we also feel apply to linking the West and rural innovators in India. One, the process of analyzing a literature can be abbreviated. We suggested that an intermediate, B, literature, can be chosen without first analyzing the starting literature. It could be done on the basis of a researcher's prior knowledge or even her hunch about which subsequent analysis would be most profitable. We will take a position in the current paper that is similar to this. Two, absolute novelty is not the only objective of literature-based discovery. Finding connections that are new to the *investigator* can be equally important – especially in commercial settings. That position, too, will apply to the current work.

Let us now consider in a conceptual sense how literature-based discovery might link Western, commercial interests with innovations at the base of the pyramid. We will suggest that West–South linkages may serve both as a source of new ideas for Western firms and as a means by which the skills and talents in the West provide advantage for the developing world. Already, Western companies realize that to compete they must innovate; and to innovate they must begin to throw out the rule book. Teece [35] argued that the rise in cooperative innovations has shifted the innovation process to make it more distributed, such that fewer organizations are truly able to innovate by operating on their own. Large companies have begun to form internal divisions with responsibilities for identifying and selecting appropriate

innovations from around the world. Procter & Gamble incorporates a strategy it calls "Connect and Develop," through which it hopes that at least half of its new products are invented outside the company. The concepts from the open-source software development community guide P&G's and other firms' efforts: There are many talented people around the world, with lots of knowledge and complementary aims and ambitions. It is foolish to think you can top this by relying exclusively on the resources within your own firm.

To identify these new ideas, companies send innovation scouts around the world, typically to research labs, start-ups, scientific conferences and other well-understood avenues for exploring innovation. Yet the base of the pyramid offers vast untapped potential for companies to identify more disruptive technologies. Databases established to support rural innovation catalog over 30,000 herbs and plants used locally in human and veterinary medicine, pest control, land conservation, etc. Mechanical and other man-made rural innovations are catalogued separately. On the one hand, Western firms with access to these databases can search for ideas that extend their portfolios. Such databases are examples of objects that forge connections among actors collaborating across an innovation network [6, 21]. Objects that mediate the relationships among actors are important for fostering innovation [33]. They include standards [14], platforms [18], and databases [41]. Web sites supporting community are emerging as new mediation forms between objects. These websites can connect potential innovation collaborators across the globe.

The National Register of Grassroots Innovation lists as available for commercialization two novel uses for motorcycles. One transformed a popular line of motorcycles, Bullet motorcycles, into a low cost device for tilling and cultivating small farms. By temporarily converting a motorcycle into a three-wheeled device with a rear "toolbar" and making various mechanical modifications to its engine and differential, small, poor farmers have the ability to farm with greater productivity and reliability than relying on livestock to pull plows. A separate innovation involves using motorcycles for spraying fields. Using inexpensive materials, the sprayer taps the motorcycle engine to create pressure that is used to spray insecticide.

How might literature-based discovery support the discovery of new applications from base of the pyramid innovations? Let us think about literature-based discovery a moment from a conceptual perspective, overlooking the details of any algorithms used for implementation. The process has two phases: abstracting, then re-contextualizing. Using lexical statistics to highlight what Raynaud's is about is a way to view the condition more abstractly. Establishing that fish-oil accounts for many of these features re-contextualizes them. Similarly, creating a drug profile and then matching it to a new disease profile, abstracts and then re-conceptualizes the description of a drug.

As we have suggested, it is not always necessary to begin literature-based discovery by examining a set of documents (as is done, say, by accumulating all the Raynaud's documents for analysis). We may be able to abstract the situation from even a single source document.

How might a manufacturer of motorcycles take advantage of literature-based discoveries to create entirely new products, even new markets? In examining a

description of the Bullet tractor, new designs might suggest themselves, and thus new products. Using pure intellect, search engines, an online thesaurus, or another type of tool for seeing conceptual relationships, any of the following physical redesigns that address various usage scenarios might suggest themselves:

- Substituting different kinds of *vehicles* for the motorcycle, including vehicles as different as handheld snow blowers, jet skis, etc.
- Finding different types of *blades*, possibly for mulching soil or helping pull lily pads from the swimming area of a beach.
- Developing other forms of *hybrids*, similarly to the way that road bicycles can swap out a wheel to become mounted exercises bikes.

But design changes need not be physical at all. For instance, the National Register of Innovation also includes an automatic spray pump for delivering insecticides. As the text of the description indicates, the spray is emitted by a special kind of sandal that creates pressure to operate a pump, thus eliminating the need for any kind of hand winding and making the delivery of insecticide convenient for someone who is walking over a small area. It is also far less hazardous than other forms of crank-operated sprayers. (See Fig. 1.) With only a little imagination and a focus on various potential new users, one can think of new uses for this innovation: a jogging shoe that keeps you cool either by spraying you with a mist or fanning you as you move; or a shoe (with a switch) that emit a loud sound (air pressure) either to scare animals (dogs while jogging; bears while hiking) or even to attract attention (lost child?).

Another innovation in the National Register is a remote cell phone-based starter that a farmer can use to turn on or off various pieces of machinery (irrigation pumps, etc.), sometimes on short notice, on a farm that can be a good hike away. Like the modified insecticide sandal, this device can be re-conceptualized. While we are beginning to hear talk of using computers to turn up your heat or turn on your lights before you come home, those images are more a matter of future than current technology. Yet, in rural India, this technology is close at hand for one who knows how to read between the lines in the literature on innovation. In rural India, this technology was produced out of necessity and, once published in the Register, the idea becomes a public good. However, determining which additional applications are the most appropriate private goods with the greatest market potential (a remote car starter that can operate at a distance far greater than similar devices that interact with a car's starter via weak radio waves?) is a matter of business discovery.

4 Discovery: West to South

To this point we have considered innovations whose genesis was with rural innovators in India, and whose broader application might be in more developed, Western markets. We now briefly consider how this flow of innovation might be reversed: using innovations in the West in contexts for which they were not originally intended. In this case we can consider Western markets through source-based models of innovation, and rural areas through user-based innovation models.

Automatic spray pump for insecticides

Background

Parbatbhai has a natural aptitude towards working with machines and creating new gadgets to make life easy. When he started earning enough to support has experiments first of all he made some modifications in the engines of 'Luna' and 'Bullet' two wheelers and learnt about tractor repairing. His next project was to develop a fuel-efficient submersible pump for drawing water from the wells. It took him three and a half years to develop the pump. In this new device he has replaced the electric motor blow with a hydraulic motor that runs on oil circulation. About 8 to 10 litres of crude oil for 24 hours is required to run the motor.

Invention of the spray pump

Parbatbhai used to spray insecticide on cotton crop in his field. He soon realized the tiresome and dangerous nature of the job of spraying of insecticides from the available pump. The pump required continuous winding of the handle, which was a very tiresome job. Along with the danger of the liquid spilling and harming the farmer was always there. Then, the cost of repairs was an additional burden on the farmer. These discomforts made him think of developing a spray pump, which would be rid of such problems.

Construction of the pump

First he made a spray pump working on the jerks and swings crated by the farmer's walking movements. When the farmer walked carrying the tank on his back, his movements gave jerks to the tank and insecticide was sprayed. But there was a practical problem. This pump was large and got very heavy. And if the tank was of a smaller size the liquid did not create adequate pressure. More over, it was costly also. Therefore it was not practically useful. Parbatbhai then chanced upon the invention quite accidentally. While he was making a pump he found that the tank was leaking. The leakage could not be located even after intense search. So he filled the tank with air using a foot pump. When the tank was full water sprayed out from the place of leakage. He got the insight he was waiting for to spray the pesticide using with air pressure! Then he got the idea of using air sandals in the place of screw pumps and was successful.

This spray pump did not need any winding of handles to spray because the sprayer had to wear a special kind of air sandals designed by Parbatbhai. These air sandals created air pressure, which got exerted on the tank and sprayed the liquid outside. This saved time, energy and labour cost.

Utility of the pump:

There are a number of advantages of this pump, which are as follows:

Present Spray Pump	Pump developed by Parbatbhai
1.Works only by winding of handle.	1. No need for wind a handle.
.2.Danger of insecticide spill.	2. Insecticide does not spill.
3.Winding of handle is a tiresome job.	3. This strain is not there in this pump.
4. Spray is formed by winding the handle.	4. Spray is formed by air pressure.
5. Needs repairing often.	5. Very little need of repairing.
6. Capacity 16 ltrs.	6. Capacity 16 Ltrs.
7. Weight 6 to 7 kgs.	7. Weight 2.5 to 3 kgs.
8. Needs replacement of washer	8. No washer at all.
9. One person can do one spray	9. One person can do two sprays.
10. One person can run only one line.	10. One person can run two separate lines.
11.Costs Less.	11. Cost is more compared to the type available in the in the market.
12. Labour cost is more.	12. Labour cost is less.
13. Needs a mechanic for repairing.	13. An ordinary farmer can do the repairing.
14. Spare parts cost more.	14. Spare parts cost less.
15. Spare parts are available in town, cities only.	15. Spare parts are available in the villages also.

Use by other farmers:

Parbatbhai's invention is not yet much known. He used this pump for the first time in his own field this year. He wishes to let his invention spread to all parts of the country.

Future Planning:

Parbatbhai has decided to get a registered trademark for the pump, and then get it patented for wide scale production. He wants to make a good quality item which rarely needs repairing and does not create problems.

Fig. 1 Entry in Indian Innovation Database on sandals that spray insecticide

Supported by different business models and having different technology formats, various "literature" databases are potentially available to help move innovations from the West to the South; these databases create interactions among knowledge originating from diverse and previously disconnected sources [38]. InnoCentive, a business begun by Eli Lilly, attempts to find "problem solvers" with solutions for "problem seekers" and facilitates the transfer of intellectual property rights. Covering areas such as chemistry, biology, and materials science, the potential of this literature for supporting the needs of the developing world is apparent. The commercial nature of the business may rule out its applicability for this purpose, however. yet2.com operates somewhat similarly, considering itself a virtual technology market for identifying, leveraging, and brokering deals surrounding intellectual assets. As part of its massive efforts to create innovation networks through its Connect + Develop program, Procter and Gamble uses yet2.com's search technology to allow others to take to market some of the 27,000 patented ideas it has but does not intend to develop. Some of these it simply donates, receiving tax benefits but no other compensation. One example of a technology that P&G holds that might support the developing world is a low-power electrolysis technology for disinfecting a water supply. They suggest the technology is scalable, kills most pathogens, and runs on a variety of power sources including batteries and solar. See Fig. 2.

Other business models are more readily applicable for making technology accessible to those in the developing world. OneWorld Health, a non-profit pharmaceutical company, finds discarded drugs that other organizations may be willing to donate for new uses in the developing world, and then takes the drug through the normal stages of drug research, screening, testing, and, ultimately, manufacturing and screening. It then arranges for manufacturing in the developing world (to produce jobs) and ensures the drug's distribution to those in need.

Electrolysis Cell Inexpensively Disinfects Water

All the world ultimately obtains its water from local, natural sources. Not even the best municipal water system in the developed world, however, is 100% effective at killing and removing water's pathogens—and many parts of the world don't have even that. This low-power electrolysis technology can disinfect a reservoir of water such as a storage tank or pool, or be placed in-line to the water supply to kill the bacteria, viruses, parasites, protozoa, molds, and spores that find their way into the water used for drinking, cooking, bathing, cleaning, and other personal uses. Scalable up or down, the technology can run on current, batteries, or even on solar power. Efficient, effective, and relatively inexpensive to manufacture and operate, the decontamination cell makes water safe.

Benefits Summary

• Disinfects water inexpensively. • Creates a dilute solution of mixed oxidants to disinfect water. • Inexpensive to manufacture. • Inexpensive to operate. • Able to be packaged in many different forms suitable for a variety of applications. more

Development Summary

Electrolysis cells have been created and produce mixed oxidants. A cell has been incorporated into a spray bottle, where it runs on two AA batteries. more

IP Summary

This technology is supported by 2 US patents. more

Fig. 2 Water disinfectant listed on yet2.com

The BiOS initiative also directly addresses the needs of the developing world. Following an open source (OS) approach in biology (Bi), the initiative supports collaborative development of innovative biological technologies, providing open access to patented and unpatented intellectual property to those traditionally shut out (such as the public sector), while still protecting commercial rights from developing new products. BiOS provides a set of tools, including a literature database providing information about both technologies and patent/IP properties.

5 New Frontiers in Literature-Based Discovery

This article has suggested that innovators in rural India have ideas that may potentially be brought to market with success if appropriate linkages with Western organizations are established. Likewise, we have suggested that technologies in the West have the potential to make significant differences in the lives of the poor. Innovation networks in both the West and in rural India serve as a source of exchanging ideas, technologies (and sometimes encouragement). These networks are virtual, with all exchange being mediated electronically over the Internet. Almost all of the information representing the content of these virtual networks is in the form of textual documents. Thus, there are literatures supporting innovation – but literatures far different in size, uniformity, tagging, and searchability than is a collection like MEDLINE.

This presents new research challenges. Key will be identifying the most appropriate kinds of search tools to uncover the unintended applications of, or modifications to, technologies. Search engines supporting two-stage retrieval from A- and then B-literatures promote a type of analogical searching in customary literature-based discovery. Additional tools are needed to support innovation discovery. There is a need to generalize from a small number of textual descriptions so that an innovation's potential value is not "obscured" by a precise description. From these broadened descriptions, tools for finding appropriate new contexts would be useful as well. One can imagine tools with certain resemblances to ARROWSMITH providing assistance in circumstances where one is seeking to understand more fully potential connections betw een an innovation and a new context. The challenge is to understand the nature of literature-based discovery in the context of linking West and South, wealthy and poor, innovation and commerce – for the betterment of all.

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