

Opening new doors to new bio-businesses and their novel products and processes

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Innovative products and processes are key to bioenterprise and the creation of successful bio-based businesses and economies. To create new and improved market-ready products, genuinely novel technologies and business advances are usually very necessary. These are exciting and rewarding – but also complex, exacting, expensive and risky, requiring new, often radically new, ways of scientific and business thinking and working by both individuals and companies with collective ambition, imagination, determination and conducive working environments.

In this article, ways that could help emerging bioenterprises succeed are discussed, including how to work more innovatively and combine economic success with contributing ‘people’ and ‘planet’ benefits. How NamZ, now called WhatIF Foods, an emerging bio-business, began, started work and developed its first products is described, giving insights into its strategies, the multiple different challenges faced, the various advances necessary to overcome them and the range of skills required. WhatIF’s approach is to identify unmet needs, unsolved problems and under-researched opportunities – and then to devise, invent and develop a stream of new products to meet and solve these, together with processes to make them, in ways that benefit people (such as farming communities) and that are not just sustainable but can actually reverse environmental and related problems. Then WhatIF develops markets for them – right through to new product launches by partner or subsidiary companies each specializing in manufacturing, marketing, distributing, and selling specific products.

Introduction

An important aim of this article is to give some readers a first awareness of bioenterprise, help others to consider it as a career option and even inform those with inventions to take them forwards.

This article and the company and products it describes are based on the understanding that to be truly competitive and successful, new ventures and their founders need to devise their very own new and different approaches, whether aiming at entirely new products or at superior versions of what is already available. This is why our company is now changing to ‘WhatIF Foods’ as it moves beyond R&D to a more manufacturing and sales focus, and why it is hoped that this article will ‘open new doors’ for life scientists, their products and the benefits they provide.

Here is an account of how the key factors for success for this startup were identified and combined into effective ways of working that integrate the range

of different technical and business activities that are essential for success, of which lab research is only one of very many. These approaches proved vital in helping to identify opportunities and devise, invent, develop and commercialize WhatIF’s first three novel products, so that after only a comparatively few years after starting with nothing, product sales have already begun – but their true economic, environmental and ethical potentials are still to be achieved as product development and sales continue and expand.

Consequently, although based on life science research, this article is not a scientific research paper describing new, experimental findings. Rather it describes and gives conclusions and opinions from experience about how a new bio-business has progressed so far, how the company began and has made progress, and the scientific approaches taken. Then a general overview of its products and the processes to make them is given – together with the technical and business strategies and the ways of working adopted, the market needs they

have been developed to meet and the customer and other benefits they provide.

What are bioenterprises?

Bioenterprises are complex blends of technical and business innovations with the entrepreneurial spirit required to devise, invent, innovate and commercialize novel products and industrial scale processes to make them much more than the sum of their parts so as to meet unmet needs, solve significant customers problems and take advantage of new opportunities.

The journey from market research through to sales has immense potential but can easily fail if even one serious problem emerges, such as safety concerns or IP rights. In particular, never forget that poor cash-flow control is the commonest cause of business failures! This article touches on many of the key technical and business factors required for success that may help future bioentrepreneurs since these apply generally, irrespective of the specific technologies, products and markets involved.

Please note that when 'product' is referred to in this article, it does not mean the product of a lab experiment or even what can be made in a pilot plant. Instead, it refers to that same molecule or material, but crucially for which a large-scale need and future customers have been identified, which is scalable (including the raw materials and equipment required to manufacture to a consistent quality) and which is cost effective, safe and legal. That is the 'product' of investors and salespeople. Likewise, when 'technology' is referred to, it means science and engineering that has been scaled up to a significant degree and shown to be probably safe and cost effective, etc., and not something still in the lab, however promising.

It is very important to emphasize that life sciences are essential for taking initial 'catalytic steps' in creating entirely undreamt-of new products with major benefits. But new science only becomes valuable when developed into new or improved technologies that are scalable and cost effective and make processes, products or services with benefits and of value to consumers or other companies. Then, once new products are widely adopted, new bioenterprise companies would have been created that create many livelihoods for people, little different from those making and selling cars or phones, etc., and which may not even require a basic science qualification. These bioenterprises then generate tax revenues to provide for those who are sick, unemployed, old, etc., as well as funding for further R&D – so completing the innovation cycle!

Irrespective of the magnitude of the initial technical advance made and the future value of the new product it

has made, many other advances are necessary, and skills required to solve them. So, much of what is required to manufacture a new product is not life science at all. Thus, scaling-up a process and purifying, concentrating and isolating products involves quite different chemical/biochemical/process/mechanical engineering approaches and equipment to those used in the lab. Then there is product formulation, packaging, marketing, distribution, sales and even consumer psychology now.

This means that, unless this range of technical and business skills can be sourced, products can only be taken to market by selling or licensing it to much larger companies, but for only a small fraction of their eventual values. Thus, to maximize the impact of a new product, a key requirement of bio-businesses is their careful gradual building of their resources to give them fully integrated capabilities.

Getting started

As an illustration, here is the step-by-step story of WhatIF and how a new bioenterprise began: its strategy, the new advances that underpin its first emerging products, the range of activities involved and what has been learnt from its successes and failures made while inventing and developing new products and processes and then beginning manufacturing and sales under its new name of WhatIF Foods. Describing a startup may give a more complete view of the challenges ahead since just one small group has done everything, whereas in larger companies different activities are dispersed among separate groups, often internationally.

WhatIF's focus is the Asian food market. Its first three products are very different from each other as each meets entirely different market needs, and so required very different technical and business approaches to be developed. These are now on sale or close to sales, each operated by a separate company fully integrated from raw material sourcing to sales.

1. WhatIF began in January 2013 with a surprise call from an old friend, Christoph Langwallner, with an irresistible suggestion. In advance of formally starting the company, we were busy planning for a whole year.
2. The first step was to devise a new approach – building what we called the 'EarthNatural' vision and a plan to make it real, combining all the key factors to minimize the time, costs and risks to market. As well as economic success these included regarding the planet and ordinary people as stakeholders, by providing significant, practical social people-related and environment-planet benefits, including how to mitigate some of the multiple, simultaneous, interacting problems causing the environmental crisis

and its consequences. Then much time was spent seeking market needs that need new products to satisfy them, rather than searching for uses for scientific advances that rarely have any immediate application. One such need was to create genuinely novel nutrient-rich food products that will become as affordable and nutritional as possible to mitigate global inequalities in nutrition, which include not just hunger but also health, including the cognitive development of children.

3. WhatIF started in Singapore in 2014 as a bio-business to invent and bring to market new food products for Asian customers, but crucially with the potential to disrupt the markets they will be sold into. WhatIF was a 'zero' startup, with no resources, staff or lab and certainly no IP or even research results to build on – but with angel investors sufficiently convinced of WhatIF's 'hero' vision and plans to provide startup finance.
4. Then came the task of identifying compelling opportunities: whether market or society trends, long-standing problems of companies or unmet needs of consumers that they may not even be aware of! But we believed that with imagination and determination powered by the combination of startup dynamism, the need to become financially self-sufficient plus the environmental imperative to contribute to a sustainable future, some new product could be devised and made on a scale that if widely adopted could make a real difference.
5. Next came the 'ideation challenge' of devising ways to meet, solve or take advantage of these needs, problems or opportunities in the form of novel but credible new product and process concepts, based perhaps on new materials or technologies that could be cross-applied, new unproven advances or some complementary combinations of these with established technologies – encouraging new suggestions and spending time as a group deliberately exploring their merits before analysing their potential proved productive.
6. Importantly each new product concept was then debated to select the most promising, by everyone, from intern to CEO – with many thinking beyond research with a multitude of questions! Are the raw materials available? Can the process be scaled up from lab data? Is the priority cost, speed or quality? Do we have people with the skills needed? What will be our product's competitive advantage? Is it patentable? Can it be made safely? What will the cost of sales be? Which is the best business model? Who could be our first customer?
7. Then to the lab, to carry out feasibility studies to obtain proofs of principle, proving utility, value, safety and potential for manufacturing, marketing

and sales while desperately hoping to identify a best candidate new product with real success potential. But rather, we created a slight problem as instead we found four worth pursuing!

...Fast-forward 5 years and what has become of our choices and how well did we implement our vision?

8. The quality of WhatIF's research has now been proved at scales of manufacturing very many orders of magnitude greater and also by the increasing acceptance of its products by customers, both consumers and companies. R&D continues on the next generation of products and providing support to its first products described later that are being manufactured, marketed and sold by WhatIF Food's companies. Its manufacturing-scale processes and their products embody, respectively, the technical advances made to meet their market needs, problems and opportunities, and the advantages and benefits of the products made.

The products

Product 1: A healthier, lower cost, low oil content fried noodle and the manufacturing process to make it

World-wide 116 bn 40–45 g servings of instant (ramen) noodles per annum are eaten – 80% in Asia, and with China easily the largest market. A wide range of products are made, most of which have been deep-fried in palm oil to give a range of flavour, colour and mouthfeel. However, fried noodles typically contain approximately 20–25% oil that replaces the water lost during frying, making them not the healthiest of meals. Also, the oil used is their most expensive ingredient. These huge quantities of oil cause tropical forests to be destroyed to make monoculture palm oil plantations, destroying ecosystems and their species such as orangutans and generating waste frying oil and pollution from palm oil refineries.

So, our challenge was how to make noodles with satisfactory fried-oil flavour, colour and mouthfeel using a very reduced amount of oil, and quickly so as to maintain high manufacturing productivities and then to scale up via pilot and demonstration processes. This is now possible by combining three technical advances.

- Mixing a limited amount of oil into the noodle dough, so that the final noodle product contains only 6.5% oil, a 75% reduction and with no oil used in deep frying anymore.
- Instead, the 'all-oil-inside' noodles are heated in a stream of hot air that develops their colour, texture, mouthfeel and very importantly an authentic fried-oil flavour by generating *in situ* molecules such as *trans*-2,*trans*-4-dodecadienal.

- To further enhance the flavour of the noodles, natural plant extracts and plant homogenates – garlic and *Moringa oleifera* – are included in the noodle dough as sources of enzymes and flavour precursors, antioxidants and anti-diabetic properties.

Consequently NamZ has developed its new healthier, low-oil NoodleZ product that is now sold, including as part of WhatIF's range of foods. The new full-scale manufacturing line developed is 75 m long and its air-frying stage uses equipment adapted from what is used to make toilet paper! This new process reduces the volumes and cost of oil used in the product, especially to air-fry them, and so should result in very considerable *pro rata* reductions in deforestation and energy consumption.

Product 2: A manufacturing process to make Kecap manis sauce using a lower cost, much more readily available and sustainable raw material

Traditional Kecap manis sweet soy sauces are extremely popular especially in Indonesia (population 276 million) and some other Asian countries, with some sales globally. They have a unique and complex sweet-savoury flavour containing a wide range of aroma chemicals such as the furanones sotolone and abhexone. However, the rising demand for these sauces from a growing and more affluent population cannot be met. This is because coconut sugar made from sap from coconuts is the main ingredient and coconut palms take 8–10 years to produce nuts, and then only around 30 each year. They are mostly farmed by smallholders, and since coconut sap is taken from their inflorescences, no coconuts are produced and so farmers lose copra as a food and other useful materials such as coir and fuel.

This challenge required finding a combination of a low cost and much more abundantly available, sustainably produced and minimally processed raw material, and a microbial strain that can grow on it and produce the required combination of flavour molecules. To meet this opportunity, we carried out chemical and organoleptic evaluation, hypothesized how the identified flavour molecules could be produced and collected soils from across South Asia screening them for required microorganisms – but none were capable.

However, two different specially selected microbial strains were found that can grow together under the same fermentation conditions in unprocessed and unrefined raw sugar cane juice and that have complementary metabolic activities. Together these produce a syrup that, when heated to allow evaporative concentration and Maillard reactions between reducing sugars and amino acids to take place, has an attractive flavour. Subsequently, some soy sauce is added to give a very acceptable product with very similar aroma, flavour,

mouthfeel, colour and lustrous appearance to traditional Kecap sauces.

This is an excellent complement to our noodle product as customers routinely flavour their noodle meals with Kecap sauces. Moreover, this new process does not require any purification, has been scaled into industrial fermenters in a sugar mill with a high fermenter productivity and the product successfully trialled in taste panels.

This new product shows how naturally occurring microbial strains can be found that together make this organoleptically very complex product from an abundantly available and low-cost raw material. It is also a rare example of the industrial use of combined microbial strains and provides a graphic example of how microbial biochemistry can provide new technologies not practicable using chemistry.

Product 3: Bambara nuts as a source of new sustainably produced ingredients for plant-based foods

Requirements for new products create derived demands for new processes – these in turn create demands for new raw materials with superior properties. WhatIF identified Bambara nuts as a very promising 'future-fit crop' opportunity to provide sustainable food ingredients that can flourish despite adverse climate changes and so contribute to global food security.

Bambara (*Vigna subterranea*) is a traditional, but under-utilized, legume crop cultivated by subsistence farmers throughout tropical and subtropical sub-Saharan Africa and some parts of Latin America and Asia, as a source of food and income during famines.

- Bambara nuts are very nutritious so even when eaten alone, they provide a balanced diet. A typical analysis shows they contain 15–25% protein, plus a range of carbohydrates, fats, fibre and minerals, and with the development of improved cultivars underway. Other such foods include lupin (another legume), vegetables such as moringa, and tubers including purple yam.
- Bambara is very resilient as, unlike other crops such as soy for instance which are grown on deforested lands, it can grow, and produce good crops with little water and no pesticides or fertilizers, in depleted soils and in arid climates.
- Also, Bambara fixes nitrogen and can regenerate soils depleted by intensive agriculture to allow other crops to be grown again. So, in practise, it will reduce climate change disruptions to food supplies, restore the quality and value of poor soils, allowing new ecosystems to develop and allow other crops such as corn or millet to be grown again, including by intercropping.

In this way, each sowing of Bambara will give rise to a field of solutions to dreams.

WhatIF's aim, led by its new 'WhatIF range of foods', which start with its soups, shakes and plant milks, was to use Bambara as a key pathfinder crop to provide 'future-fit' foods. These will pioneer regenerative changes in the agri-food industry and consumer preferences through technological innovation and partnerships with farmers and other companies. Then more 'future-fit' plant foods can be developed of superior nutritional quality that genuinely nourish people rather than just providing calories, improve the quality and quantity of soils and global food quality and security, protect ecosystems and empower farming communities rather than destroying them for the industrial cultivation of crops such as soy (for instance) as, unlike soy milk, Bambara milk is made without generating any wastes. The cultivation of Bambara gives multiple benefits including soil regeneration and production of a nutritious product under climatically adverse conditions that is now being used as the main ingredient of a range of other food products.

To sum up: Each one of these three emerging products has multiple different benefits, including benefits for the environment and people, and so give multiple returns on the time and resources spent on developing them. Patent protections are being granted, and their production costs should reduce with economies of scale, as demands for these products grow.

The challenges of achieving real change and better futures through their triple benefits are huge because timescales are necessarily short because of the speed with which climate change is developing, but we have good reasons to be very optimistic. These new products also demonstrate that even very small companies are capable of developing new processes and products with global potentials for their multiple benefits.

WhatIF's integrated R&D and business development approach

Conventional basic research that seeks new information and understandings of the world and how it works has undeniably important longer-term value, but it only rarely leads immediately to practically useful products. Instead, WhatIF's strategy is to be market-led by identifying real, but often unrecognized and unresearched, needs, problems and opportunities, including consumer trends. Then the strategy is to devise ways to meet, solve and make use of these identified needs in the form of new product concepts for which large and receptive markets already exist, followed by inventing and developing new, better processes that use sustainable raw materials to make novel products with significantly superior benefits,

rather than just 'green-washing' them for marketing purposes.

The overall process 'from idea to first sales of product' starts by identifying a new need, problem or opportunity. These are then transformed by devising a new product concept that potentially meets, solves or exploits them – followed by research to invent a potential novel and practical product, process or service and the development and implementation of the invention into a marketable form.

Thus, companies need broad capabilities as illustrated by the different technical and business challenges outlined in Box 1, especially since these are sometimes as much opportunities as problems. To take just one example, scaling-up using biochemical and chemical engineering skills includes considering capital and operating costs, product isolation, purification, concentration and stabilization, safety and regulatory approvals, but in return ensures more reproducible processes that meet higher product quality specifications, reduced production costs and can achieve economies of scale when demand increases.

Furthermore, WhatIF has a genuine 'triple-bottom-line' strategy. The overriding aims it sets itself are based on products with the potential to have a combination of not just major economic successes, but also social people-related and environment-planet benefits – that are based on new processes, products and raw materials that are regenerative and can actually reverse climate change-related problems rather than just reducing the rates at which damage takes place. In practise, this triple ambition means that WhatIF prioritizes the interests of not just shareholders, but also ordinary people such as farming communities, and our planet Earth, with the aim of reinventing what we eat, how we make foods and grow the raw materials used, all by the development of new more appropriate technology, rather than focusing only on profitability using intensive agriculture.

So how has WhatIF succeeded so far despite the additional goals it has set itself? The answer is easy: to include all three goals as important criteria when selecting which of its new product concept opportunities to work on, and selecting those with the best combinations, even if that increased the challenges ahead. This puts a huge onus on WhatIF's flexible and collaborative style and capabilities to invent, improvise and innovate to make the genuinely novel technical and business advances needed to market a stream of disruptive products with 'triple benefits'.

However, paradoxically this proved beneficial as it pushed WhatIF to improve and become more inventive, leading to better processes and products than if we had only chased profitable returns on investments. It also facilitated the development of a new, fully integrated and disruptive R&D and business development capability

Box 1. WhatIF's step-by-step approach to creating new, useful and valuable processes and products

There can be significant changes in the order steps are carried out and additional steps may be needed for some products.

- First the identification: of economically, socially and environmentally important real-world unmet needs, long-standing problems and new opportunities such as new raw materials, scientific discoveries or business models; or a change in the economy, customer preferences, values or behaviour that creates new opportunities.
- Then ideation to devise genuine New Product Concepts for future products and processes that could potentially meet these needs, solve these problems, exploit the opportunities identified and in doing so benefit people, the planet and shareholders.
- Use of Selection Criteria based on Key Factors necessary for technical and business successes to evaluate and identify those New Product Concepts with the greatest potential.
- Invention: of potential novel, inventive and practical products or processes that provide proofs of concept that meet or solve a need, problem or opportunity in feasibility studies.
- Completely focus on just those new product candidates with the most promising business prospects based on WhatIF's economic, people and planet values, combined with their likely market sizes and values, business models, resources required, costs, timescales and risks involved.
- Optimization and development: of prototype new processes and products, including detailed raw material sourcing, process and product scale-up to meet productivity, cost and product specification targets, meeting IP and safety and regulatory requirements, as well as identifying end-product applications, company and market development and financial estimates for returns on investment.
- Very importantly there is the evaluation of the prototype products by potential customers to prove they can satisfy market requirements and that customers are receptive to using them while crucially meeting cost and quality targets in every production run and meeting consumer expectations and satisfaction at every mealtime. This 'beta-testing' is broadly comparable to the 'Fallibility Principle' for proving scientific knowledge (Popper, 1959).
- Next, innovation involving the development and implementation of the product into a marketable form to make it scalable, safe, legal, cost effective and convenient to use, thereby making its benefits and value available to its customers and users.
- Transfer to subsidiary companies for optimization during manufacturing trials and market development prior to establishing marketing, distribution and sales capabilities.
- Product launch!

by combining many distinct aspects into its overall approach (Box 2), and implemented as in Box 1.

As a result, WhatIF's first products are beginning to prove that these improvements and a collective will to succeed can successfully create a steady flow of new products with combined economic, social and environmental value and benefits. Thus, beginning from a 'cold' startup, our products are already, or very soon to be, in production and on sale, and so delivering on these goals. Moreover, the extent of the triple-bottom-line commitment is shown by Bambara which began simply because it offered such a promising opportunity to meet the demand for 'future-fit crops', with no hint of any particular product it could give. This required us to find economically promising new product concepts to test. As a result, the Bambara milk product is in production and is the first in a Bambara-based product pipeline.

How bioenterprises and their products can succeed

Developing the capability to consistently generate radically new product concepts and evolve from just a dream into the reality of a growing business with satisfied customers and a profitable company so that it can fund its own R&D, etc., is truly challenging. Doing so may well seem next to impossible, especially given the competition from much larger, well-established and better financed companies – startups often begin with very few resources, staff, and money...

But with conviction, determination and some talent, it is regularly done!

Startups often begin with 'can-do' attitudes to what is possible, plus 'win-or-bust' determination, combined with the great advantage of the freedom to adopt whatever new approaches they believe might work. Then, almost uncannily, a lack of resources frequently up-regulates

Box 2. WhatIF's integrated R&D and business development approach

- WhatIF works from basic principles rather than starting from published results, so minimizing competition and generating stronger IP.
- WhatIF devises ambitious new 'stretch' technical approaches to test, simply because success would be such a huge step forward, even if a positive result seems unlikely and unfamiliar skills must be mastered.
- WhatIF benefits from a diverse, versatile and integrated range of technical and business skills, ranging from microbiology to law. For instance, its current products have relied on its expertise in microbial screening, fermentation, enzyme-based and reaction-flavour generation, food processing and product assessment skills. These contribute to identifying and evaluating a wide range of product opportunities, overcoming challenges as they arise often unexpectedly during product development, and to ensure the best ways to deliver social and environmental benefits.
- WhatIF selects and rapidly focuses on implementing just those products with the overall best prospects.
- WhatIF's approach integrates the multiple different key factors for success into plans for developing new products, the processes to make them and the markets for them. These are often different but interrelated activities, and so require different skills and approaches and frequent reviews of all technical and business aspects, even if done informally.
- To help, communications are facilitated, irrespective of people's roles and positions. This is by providing opportunities for everyone to work and socialize in ways that encourage those vital productive interactions that would otherwise never occur and to facilitate decision making, such as by the CEO being just another person in a large office, so that anyone can ask questions such as 'Why is the product I have worked so hard and successfully on to be sold at a low price?'

human ingenuity, which leads to unanticipated approaches and novel ways to minimize the time, cost and risks involved in new product development, devising new uses for them and even the creation of entirely new markets. Creative combinations can be made of existing technical and business know-how, re-purposing existing technologies and identifying relatively unrecognized opportunities which can allow rapid progress to be made without lengthy basic research.

Startups and other small companies usually cannot directly compete with larger companies. What they

can do is to work on opportunities that are too small or risky to interest the larger companies. Then if real breakthroughs can be made and high growth potentials and/or reduced risks identified, small companies can quickly become the sole supplier into rapidly growing markets for its new products, even without having to completely optimize operations. Then, once sales are established, remaining R&D can give improved products to compete with emerging competitors. Meanwhile larger companies may be slower to respond because of their necessary focus on existing products and sales and needing to get broad internal consensus on new initiatives. So, paradoxically, the best hope could be small companies with minimal resources, who at this very moment can't change anything, but are quicker, more flexible and desperate to achieve change and grow.

A special opportunity for bioenterprise is that we have no 'Earth Version 2' to fall back on and are already increasingly suffering from the 1.2°C increase in global temperature above pre-industrial levels, and close to the 1.5°C tipping-point rise identified in the 2016 Paris Climate Change Agreement. Food products and their raw materials are mostly agricultural products, and agriculture is especially vulnerable to the multiple disruptive effects of climate changes, including losses in soil quality and quantity. Even worse, threatened ecosystems contain the diversity of plant and microbial species that are vital as sources of the future solutions to climate-change threats, but that will not survive if they cannot adapt fast enough.

These multiple different, important and urgent problems do offer new opportunities for bioenterprises, and already many proposed solutions require new future-proofing bioproducts and bioprocesses. So, if scalable and cost effective, regenerative technologies can become standard requirements with public and political acceptance and regulative support. Then they can become major drivers of innovation and market-disrupting forces with great benefits for all stakeholders.

Thus, what NamZ and now WhatIF are doing may help like-minded companies to also become agents of change for Earth, its peoples and wildlife – using the problems created by global climate change as opportunities to develop regenerative technology to 'go back to the future' by actually reducing problems fast enough to reduce them back towards pre-industrial levels and restore stable ecosystems, farming practices and global food supply and quality.

But nothing worthwhile gets done without the right people, especially if they have diverse but complementary skills, experiences and ways of working – ideally flexible people and problem-solvers with the ability to learn 'on-the-job' and entrepreneurial enough to set themselves ambitious 'stretch' objectives such as to try things because 'What if they worked?' would be

Box 3. Six key points

From WhatIf's 8-year-long and counting experiment in science, technology and bioentrepreneurial business, what may be learnt?

- Taking a customer and market-led, and thus a 'need and problem-solving', approach is important as it frequently stimulates new thinking and gives some certainty that customers will want the product. But to convince customers to not just be interested but actually buy newly launched products, they need substantial and sustainable competitive advantages over their direct and indirect competitors, as well to be competitively priced and to also have all the benefits that these existing products already have and that their customers value.
- Ideally all new products should have market-disrupting potentials to eventually change market leaders and redefine customer's expectations by making significant step-jump/qualitative innovations – such as a first process to make a sought-for material, a molecule with a new physiological activity or setting very much higher environmental standards. This is rather than just making small incremental improvements in performance, cost or ease-of-use. Then customers can be offered well-differentiated products with very superior benefits that established competitors cannot match and that make them very attractive to their customers, so that they gain large market shares and dominant market positions.
- Another advantage of disruptive product concepts is that even if things don't work quite as hoped, it is still likely that a worthwhile product is still possible.
- Genuine innovation, from devising new product concepts through to their market launches, is very complex, especially when aiming at multiple goals such as to also regenerate environmental problems. Genuine innovation often takes place when different technologies are brought together and usually require several different technical and business advances to be made, and so raise a range of different challenges requiring different technical and business resources. Also, the development and commercialization of a marketable product or process is as challenging as making the initial technical breakthrough and usually takes longer and costs much more. So, decision making requires the ability to make sound judgements and decisions in situations involving multiple different factors and risks that can be inter-dependent, expressed qualitatively or quantitatively and change quickly.
- WhatIf has developed a generic and disruptive R&D and new product development approach that has become its culture or mind-set. The approach combines and integrates key factors and steps from new product identification and development and business development. Consequentially, it can relatively quickly invent and develop its own disruptive products and processes which, if attempted more conventionally, could require much greater resources.
- Reproducibility is vital when creating new large-scale processes and marketable products, for instance to maintain process productivity and product quality while going from lab results through process and product development to manufacturing and especially their use by customers. This may appear to be very different to how basic research is done. However, these two activities both share reproducibility as an over-riding criterion for success. This is because, in basic research, reproducible results are absolutely necessary if other researchers are to use new methods, information and understandings to help their own research, and hence the need of peer review of papers.
- Perhaps the 'Key' key factor for success is the collective efforts and determination of people with their combinations of scientific, technical, engineering and business skills needed to solve challenges encountered 'from idea to sales' – whether screening for a new microbial activity or securing raw materials, through to making commercial agreements or designing novel manufacturing equipment.

such a big advance. A motivation is that, to succeed, small companies must grow rapidly, which can create career opportunities for people to take on new roles and greater responsibilities and gain huge experience in just a short time! Also, there are excellent opportunities to do ground-breaking science because startups have to develop very novel and inventive products not just to obtain strong patent protection, but also to make them distinctive and give them the strong competitive advantages needed to break into their target markets. For those deciding to 'be their own boss', a benefit is the freedom to choose their own business model such as where in the value and supply chains to work or whether

to develop new raw materials, new bioprocesses, or new consumer products.

Working on something personally important and meaningful always helps. There are simple gratifications, such as creating something of real value for years to come or remembering your first sight of a small HPLC peak, while now seeing that material pouring into containers at the end of a production line en route to customers worldwide, or just the surprise of friends or family, having just seen 'your project' now on sale. But perhaps the biggest stimulus to innovation is people's ambitions and drive to prove 'My new idea really can become a

winner', especially when the effort to achieve that has put one's livelihood and reputation at risk.

Conclusions

This article highlights the contributions innovative food products and processes make to bioenterprise. It describes how creating new and improved technologies, processes and market-ready products is a complex, exacting and risky, but very rewarding, endeavour requiring multiple novel technical and business advances and new ways of thinking and working by companies and individuals. Key points (Box 3) show that while top science can be a great way to start, it is only the very beginning of the long journey to a saleable product.

Climate change and the multiple different problems it causes create new opportunities for bioenterprise. NamZ, and now WhatIF, is used as an example to show how its technical and business approaches as a tiny startup have enabled three different but equally novel food products and processes to be taken relatively quickly to market at relatively low costs, and as a new bioenterprise with benefits for people and the planet. In

doing so this indicates how the future economic values of their social and environmental benefits could far surpass their R&D and product launch costs, and so make the development of other new technologies to counter and reverse the effects of climate change a very worthwhile economic opportunity, as first proposed in the Stern Review Report of 2006.

Finally, I have tried to weave together many different themes relating to bioenterprise that may interest readers with no background in bioenterprise, and perhaps make them aware of it as a career option or even encourage others to take an invention forward. Then more, and yet more, new doors may be opened so that, as the artist and poet William Blake wrote, "What is now proved was once only imagined".

Acknowledgements

To those who left secure jobs for the organized chaos of a startup and to those who so believed in our vision that they risked investing before any green shoot whatsoever had emerged. ■

Further reading

- World Instant Noodle Association, Instant noodle market and other information, instantnoodles.org
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After a PhD in enzymology, Peter Cheetham worked in biochemical engineering at UCL using membrane-bound enzymes to help develop the first clinical bioassay for cholesterol. Next at Tate and Lyle, he developed biocatalytic processes for less calorific and cariogenic sugars, the high-intensity sweetener sucralose, and in starch processing. Then working for Unilever's flavour and fragrance subsidiary, he developed a range of natural flavours such as furaneol and γ -decalactone and then food and cosmetic ingredients such as ceramides. He left to found Zylepsis, continuing to apply biocatalysis to make natural ingredients. Then after 10 years, a spell working in technology transfer, he moved on to NamZ.