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Review Article

Transforming Agriculture Research into Commercialisation: Experience of Universiti Putra Malaysia

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ABSTRACT

One of the major goals of any high impact research and development is an overall improvement in the well-being and sustainable quality of life through innovations. As universities continuously disseminate innovations from R&D activities, many prototypes and lab-scale products, whether tangible or intangible, can be made available for public use. The success of bringing these innovations to the marketplace depends on the quality and capability of the technology transfer office to lead different types of activities, engagements, negotiation and inclusiveness towards fulfilling the needs of commercialisation partners and the market. This paper presented a general overview of transforming research output into commercialisation in the context of Universiti Putra Malaysia (UPM). Throughout this paper, different commercialization channels, the roles of technology transfer offices and multiple agencies are further discussed with a special focus on agricultural innovations and technologies. This review contributes to both academic and agricultural industry research, development and commercialization activities by illustrating current innovation produced by UPM and industry-university collaboration, conducted at a leading agriculture university.

Keywords: Agriculture commercialization, innovation, research, technology transfer

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INTRODUCTION

Academia to many seems to be a routine between classrooms and offices. The truth remains that the world of academia has had its fair share of challenges. In addition to the conventional teaching and learning processes, academicians play a vital role in conducting and supervising research, publishing research findings and collaborating with other para-academia. These publications, coupled with public discourse and lectures, are the major windows of academic research transfer outputs. The trending demand on research expansion is geared towards floating research outside of the university and proffering lasting solutions to debilitating economic downturn in related sectors. Universities are now saddled with the responsibility of commercialising research findings and innovations as a way of cushioning the many problems of the rapidly growing human population.

To achieve the desired commercialisation of research findings and innovations, a wide range of activities ranging from market validation, identification of governmental or private partners or collaborators ready for developing these research findings and innovations into commercial or marketing products is a cardinal necessity (Razak et al., 2014). Other key factors include saleable innovations, managerial support (Thiruchelvam, 2004), appealing marketing environment and trained human resource (Asmawi et al., 2013). Sanberg *et al,* (2014) and Mehta (2004) rated the average commercialisation of research findings to be 5%, a crystal clear indication that most, if not all of the research findings and innovations in the Universities are but monumental adornments kept on the shelves of our libraries and laboratories.

Successful academic entrepreneurship is a complex target requiring a continuous process and series of events (Friedman & Silberman, 2003). Brainstorming, development of a multi-stage process model that identifies the key actors and activities and success drivers associated with each stage of the innovative commercialization process are a major part of the processes involved (Mehta, 2004; Perkman et al., 2013; Sanberg et al., 2014). Public and private financial involvement is a pillar for the success of academic commercialisation of research findings (Tansey & Stembridge, 2005). In this paper, an overview of agriculture research and its commercialization to the market place through patents, trade secrets, and copyrights was discussed and highlighted based on the experience of Universiti Putra Malaysia (UPM).

RESEARCH, DEVELOPMENT AND INNOVATION IN AGRICULTURE

Agricultural research and development have always received considerable funding for the single reason of maintaining a steady supply of food and animal products to match the increasing pace of human population. The most important key to sustainable food security is innovation, through which food safety, resource-efficiency, climate changes and quality of farm products can be improved while jobs opportunities

are being created (Godfray et al., 2010; Hoffmann, 2011). Within the past century, technology and innovation have been the major drivers of both agricultural productivity and financial success of many farms and agro-related marketing.

To actually bridge the gap and disseminate the products of academic research findings and innovations to the private sector, particularly farmers and end users of such products, certain technical skills and technology must be put in place to aid in achieving the sole aim of commercialisation. The challenges of bringing new technology to market in the agricultural industry are high because it is difficult to convince and educate farmers to adopt the technology that results from new invention. A typical scenario is the iCOW Technology in Kenya (called iCOWT), a simple mobile phone application , particularly for farmers involved in animal fattening and production where they can easily track and record parturition periods or the expected length of gestation of their animals. This Kenyan farmers aided technology (KFAT) allows farmers to send SMS codes to actually register individual animals on the farm and, for example, to register their insemination dates. The technology provider in collaboration with the professional academicians in the related field of study therefore sends a prompt notification to the farmers advising them of the expected date of delivery and best days for next insemination thereby increasing farmers' awareness of the modus operandi of insemination and economic expectations. There are other farmer-based technologies with weekly tips on professional breeding systems, nutritional values, milk production and dairy management.

Hence, understanding farmers' needs, market signals and market needs is the main driving force behind successful research and innovation (Govindaraju et al., 2009; Mansori et al., 2015). In addition, upscaling agricultural innovations to determine the consistency of the results might be challenging. As an example, to obtain evidence of the efficiency of certain vaccines, fundamental research must be carried out before scaling up vaccine production (Lo et al., 2011; Ismail et al., 2012; Vakhshiteh et al., 2013). Efficiency and productivity of the world food systems must increase in order to ensure that people have access to high quality and quantity of food (Godfray et al., 2010). Achieving the substantial increases in demand for food will have greater global implications for livestock production systems in the coming decades (Kristensen et al., 2014). As a general background, the global livestock sector is growing faster than any other agricultural sub-sector and provides livelihoods to more than 1.4 billion people and contributes about 40% to global agricultural output. According to the Food and Agriculture Organization of the United Nations (FAO), global meat production is projected to be approximately 465 million tons in the year 2050. Between 2000 and 2050, the global cattle population may increase from 1.5 billion to 2.6 billion, and the global goat and sheep population from 1.7 billion to 2.7 billion. The majority of the increased demand will occur in Asia,

Africa and Latin-America. Therefore, research and innovations targeting increased animal production should be conducted to cater for the expected market demand.

A plethora of research and innovations could be carried out to include mechanical (tractors and combines), biological (crossbreeds), chemical (fertilizers and feed supplement), agronomic (new management practices) as well as biotechnological innovations (GMO) (Saenphoom et al., 2013; Abubakr et al., 2015). A total of 8075 livestock breeds are annually produced globally, which includes 1053 trans-boundary breeds, of which 490 are regional trans-boundary breeds occurring only in one region and 563 are international trans-boundary breeds with a wider distribution. These breed populations represent unique combinations of genes for production and functional traits but also the ability to adapt to local conditions, including feed and water availability, climate and disease conditions (Hoffmann, 2011).

In response to increasing demands despite limited farm lands, confined livestock production systems in industrialized countries are the source of the world's poultry and pork production and presently such systems are being established in developing countries, particularly in Asia. Moreover, modern smart farming systems (MSFS) using cameras, sensors and other forms of technology are being tested to improve irrigation efficiency or reduce use of pesticides by improving detection of diseases. Hence, any research towards improving the system will definitely benefit farmers, particularly innovations that solve regional issues (Shanmugavelu et al., 2012). A typical illustration is Kilimo Salama mobile based Technology where farmers in Swahili are offered crop insurance against drought or excessive rainfall. The technology sends information through SMS to the farmers on expected weather conditions and its effect on crop production.

Another example is the increases in numbers of animals and the higher demand in feed supply. In the intensive mixed systems, food-feed crops are vital ruminant livestock feed resources. The prices of food-feed crops are likely to increase at faster rates than the prices of livestock products. Therefore, demand for a suitable feed that is easy to grow and contains high nutritional value is pursued by the industry. Moreover, any technology towards accelerating production of feedstock will be greatly accepted.

Environmental impact, labour assessment and public concerns are among the key points that will be assessed following an impact of innovation, whereby innovative agriculture should also protect the natural resources, biodiversity, landscape, soil and water, and increase the environmental and climate benefits that farming provides, however, each of the research outcomes may raise different concerns and policy questions (McClintock et al., 2014).

Among the biggest challenges in the livestock industry are management and control of infectious diseases through the use of various biosecurity approaches including the use of diagnostics, vaccines

and other therapeutics. The burden of infectious diseases in livestock and other animals continues to be a major constraint to sustained agricultural development, food security and participation of developing and in-transition countries in the economic benefits of international livestock trade and marketing (Fitzpatrick, 2013).

Vaccines are essential biologics to control and prevent disease occurrence. In Malaysia today animal vaccine production is a multi-million dollar business. Malaysia imports vaccines and pharmaceuticals worth RM650 million annually and there is a dire need to seriously look into ways to increase locally produced vaccines. Initiating successful development and production of locally produced vaccines involves strong collaborative efforts between the universities, industries, governmental and private agencies. Several fundamental research investigations aimed at understanding responses towards infection will need to be conducted before vaccine development (Zamri-Saad et al., 1999; Lo et al., 2011; Shin et al., 2014). Many of these works have already been conducted to develop effective vaccines against local strains in Malaysia. The examples mentioned above are only a small fraction of innovation in agriculture research. There are a lot more opportunities yet to be explored by researchers and later to be commercialized in the market.

COMMERCIALISATION: AN OVERVIEW

Commercialisation is a process aimed at generating academic impact as it constitutes immediate and measurable market acceptance for outputs of academic research and innovations (Markman et al., 2008). To increase the possibilities of producing commercial innovations, more engagement with the public and industrial partners is a process that must be targeted (Berman, 2008; Martinelli et al., 2008) as this provides platforms where scientists and researchers can comfortably discuss with people from relevant industries. It is also vital that key people within the system clearly understand important concepts in commercializing university innovations like intellectual property ownership, technology transfer, sharing revenues, licensing and start-ups (Govindaraju et al., 2009; Bruneel et al., 2010). Policies may represent organization's commitment and guide operational activities, but there should be enough flexibility for things to move quickly in unprecedented but controlled ways (Tansey & Stembridge, 2005).

Intellectual Property

The innovations created in the university and the technical know-how involved are normally the intellectual property (IP) of the university. The university usually bears the cost to file for the registration and maintenance of the IP based on the evaluation of their commercialization potential or further improvements. In the usual practice, revenue generated from any

commercial endeavour of these intellectual properties will be shared with the inventors, the scientists and researchers according to the institution's policy. As there are many types of intellectual properties, it is imperative that continuous training is given to educate scientists and researchers. Filing for intellectual property rights may also involve complex deliberations related to strategic planning.

Technology Transfer Office

Many universities have established specialised structures, such as technology transfer offices (TTOs), science parks and incubators to support the aforementioned activities. These offices manned by technology transfer professionals are responsible for managing innovations from registration to coordination of different aspects of technology transfer activities (Fishburn, 2014; Sanberg et al., 2014). This is to include creating supportive internal rules and procedures (Thursby et al., 2001). Established TTOs also have structures handling disclosures, evaluations and filings, customer discovery and marketing as well as business matching and negotiations. Once a deal is established, TTOs will work closely with the legal department towards drafting and signing of agreements by the designated signatories empowered by the board. TTOs will also monitor and facilitate post licensing activities to warrant complete and smooth technology transfer from the university to the industrial partner.

Essentially, the mission of the TTO is to ensure that the university's innovations are disclosed, intellectual property protection is secured and to facilitate the transfer of the university's intellectual property to outside partners. As such, the TTO can be thought of as the coordinating hub of commercialization activities and often plays one of the most central roles in the academic entrepreneurship process (Markman et al., 2008; Wood, 2011).Policies developed will be adopted to protect the rights of researchers and to preserve core academic values as well as to protect the universities from conflicts of commitment and conflicts of interest.

In actual practise, commercialization is a complex, often non-linear process and with a lot of impediments in between stages. The challenges might start with finding public and private investment in R&D, the fluctuation and inconsistency of R&D performance, decisions about whether the innovation is worth the time, effort and expenses required to secure intellectual property (IP) protection, building a prototype to demonstrate the technology, the further development needed for commercialization and finally resulting in the successful acceptance or rejection of a product or service in the market (Boehm & Hogan, 2013; Perkmann et al., 2013; Jamil et al., 2015).

University and Industry Partnership

Universities in Malaysia have established a number of mechanisms to accelerate university-industry linkages especially in commercialization of research results (Table 1). Though UPM named its technology

transfer office as Putra Science Park, which serves as the pre-incubation hub for research commercialization, its function differs from five science parks which have been set up throughout the country by the Federal and State governments; 1) Kulim Hi-Tech Park in the northern state of Kedah, 2) Technology Park Malaysia in Bukit Jalil in Kuala Lumpur, 3) Selangor Science Park (SSP), 4) UPM-MTDC Incubation Centre in the state of Selangor, located in University Putra Malaysia (UPM) and 4) Technovation Park based at the UTM Campus in Skudai in the state of Johore. These science parks were mainly functioning as a platform to stimulate innovation among small and medium sized enterprises (SMEs) and to enhance prospects for the development of technology-based companies through university–industry collaboration (Malairaja & Zawdie, 2008). Science parks are built to foster enhanced university partnership leading to greater utilisation of university research results. These parks serve as effective interfaces between university and industry.

The financing of university research is being scrutinized in Malaysia as governments increasingly demand measures of impact and outcomes such as scientific output and socio-economic values from the grants awarded (Payne & Siow, 2003; Kamariah et al., 2012). Moreover, the direction of research has progressed from

Table 1
Commercialization division under five Research Universities (RU) in Malaysia

University	Name	Function of commercialization unit
Universiti Sains Malaysia	Sains@USM (http://sains.usm.my/)	Support start-up companies, innovators and researchers with projects or products that are close to commercialization.
University of Malaya	UM Centre for Innovation and Commercialization (UMCIC) (http://umcic.um.edu.my/about/)	One Stop Centre for IP management and legal services, technology licensing, incubator centre management, start-up business development and provides commercialization support services.
Universiti Teknologi Malaysia	Innovation & Commercialisation Centre (http://www.utm.my/research/research-support-units/innovation-commercialisation-centre/)	Focuses on developing and commercializing UTM's research products by tapping into the University's ample facilities and experts
Universiti Kebangsaan Malaysia	UKM Technology Sdn Bhd. (http://www.ukmtech.com/v2/)	Accelerate the commercialization of UKM's R&D and Intellectual Properties. It is also the Holding Company for UKM start-up companies.
Universiti Putra Malaysia	Putra Science Park (http://www.sciencepark.upm.edu.my/aboutpsp)	Assists in securing and protecting novel innovations through intellectual property processes and identifying applicable commercialisation strategies for the created intellectual property. PSP becomes the middle entity between UPM and UPM Holdings regarding commercialisation.

basic science free of societal needs to a more demand-driven science that must meet certain objectives (Amran et al., 2014). Apart from public research grants that are generally associated with wide scope projects, private contracts concentrate on short-term objectives aiming at the production of knowledge that can rapidly be used as one of the resources to fund research as the potential for commercialization is high (Goldfarb & Henrekson, 2008; Kamariah et al., 2012).

Private funding of joint ventures with private organizations are among the useful instruments for sharing funding responsibilities (Amran et al., 2014). There are two major reasons for such joint ventures. First, it is somehow cheaper for private companies to contract certain types of research to the public sector, rather than establish or expand their own research facilities. Second, universities and players in the agricultural sector in particular, usually lack the skills needed to mass produce and distribute the production of particular generated technology, which has been identified as one of the main limitations to technology distribution (Perkmann et al., 2013). Joint ventures between public and private-sector institutions is currently being developed in many countries, whereby they share the costs and benefits of research in fields such as genetic improvement, seed production, plant propagation, and veterinary products.

However, the challenges are high when collaboration takes place between two entities with totally different backgrounds and missions. The success of industry-university partnerships is determined by people who work in them. It is suggested that universities must have people capable of building and managing partnerships in order to attract industry involvement (Asmawi et al., 2013). Collaborations only work well when they are managed by people who cross boundaries easily and who have a deep understanding of the two cultures they need to bridge (Powell & Grodal, 2006; Boehm & Hogan, 2013).

Moreover, collaborators should not be troubled by intellectual property (IP). A broad comprehensive framework agreement should be developed and details must be well spelt out on a case-by-case basis. Hence, a framework agreement would save time and avoid the acrimony that might arise. Sometimes, no matter how good the innovation project, company executives tend to walk away from universities that have an inflexible approach to IP. Noteworthy, IP is an important element, but it should not be regarded as the core of industry-university relations. Moreover, it should not be viewed as the main income source. The income stream will be greater and benefits wider through university-industry partnership, where a form of partnership with industry helps to modernize teaching and learning as well as dissemination of research (Saguy, 2011).

From the traditional point of view, university-industry partnership seems difficult to apply to the agricultural field. It is generally believed that agriculture is a highly tasking profitable investment. However,

after the year 2000, the situation is changing. The upgrading of agricultural industry is increasingly prominent, which not only makes agricultural investment opportunities on the increase, but also provides good investment value for agriculture (Boehlje, 2004). However, partnerships could suffer when the focus changes. For instance, to please R&D, the research might aim to gain knowledge about emerging technologies. On the other hand, to please the business development group, it might look for start-ups that could become acquisition targets. While to satisfy the Chief Finance Officer, it might aim for a certain threshold of financial returns. Hence, it is important for each side of the partnership to understand the other's perspective, whereby all collaborators understand each other's roles and motive as incompatibilities hinder the development of productive collaborations (Perkmann et al., 2013). In Malaysia, the theory of research to commercialization has been successfully put into practise by University Putra Malaysia.

Commercialisation Experience

University Putra Malaysia has successfully established multidisciplinary research teams with cutting-edge science and technology projects. Most of these projects have been identified and developed in accordance with governmental policies and national needs. Academic entrepreneurship in UPM actually began well before the TTO's involvement (namely Putra Science Park). It started in the university's diverse array of laboratories and research centres, which is the place where faculty members and their research teams engage in the wide range of research. The outputs and innovations produced later become the technologies which Putra Science Park (PSP) sought out for its commercial potential. There was enormous commercial potential derived from the effort and to date out of 1600 total IPs, 94 of them have been successfully commercialised. In total, UPM has recorded above USD 10 million gross sale.

Putra Science Park (PSP) UPM is a special dedicated division for commercialization and innovation of research work with researchers to attract corporate partners that can bring inventions and discoveries to the market through technology licensing agreements. PSP coordinates the entire process from negotiation to completion of licensing agreement towards granting rights to commercialise technologies to companies. PSP ensures the needs and interests of all parties involved are fulfilled. The participation of various financial hubs has been recognized and triggered to enhance the efficacy of PSP and university incubators for an expanded research commercialization. World Halal Innohub is one of the success stories of partnership effort between Halal Development Corporation and UPM to increase innovation capabilities for the Halal Industry. The program provides common office facilities, shared services and shared facilities, as well as centre's capacity building programme such as intellectual property protection services, education and training via mentoring and coaching programme. As an impact, this program has successfully created jobs, commercialization

of high-impact technologies and wealth creation for the halal industries.

For several years during the early establishment of UPM, technology transfer was conducted through informal mechanisms such as publications, training, and meetings with the clients as well organising technology exhibitions. To date, technology commercialization in UPM is realised in either business matching, negotiations or technology transfer with various funding opportunities (Figure 1). At this stage, the PSP serve as a platform to balance and align the broad interests of the university, including the researcher, with the external interests of entrepreneurs and external business partners needed to commercialize the technology. It is important to note that the PSP may engage multiple partners or enter into exclusive agreements when commercializing, and the research shows advantages to both approaches depending on the nature of the innovation (Colyvas et al., 2002). Whether there are multiple partners or an exclusive arrangement, the collective group of key stakeholders must decide on the best way to move forward. This leads to the third stage in the academic entrepreneurship process: selection of the optimal commercialization mechanism. The most commonly used formal mechanisms by which universities transfer their intellectual property to any interested parties is via technology licensing agreements. Alternatively, the university may help potential entrepreneurs to incorporate a completely new start up business entity, typically called a 'spin-off.'

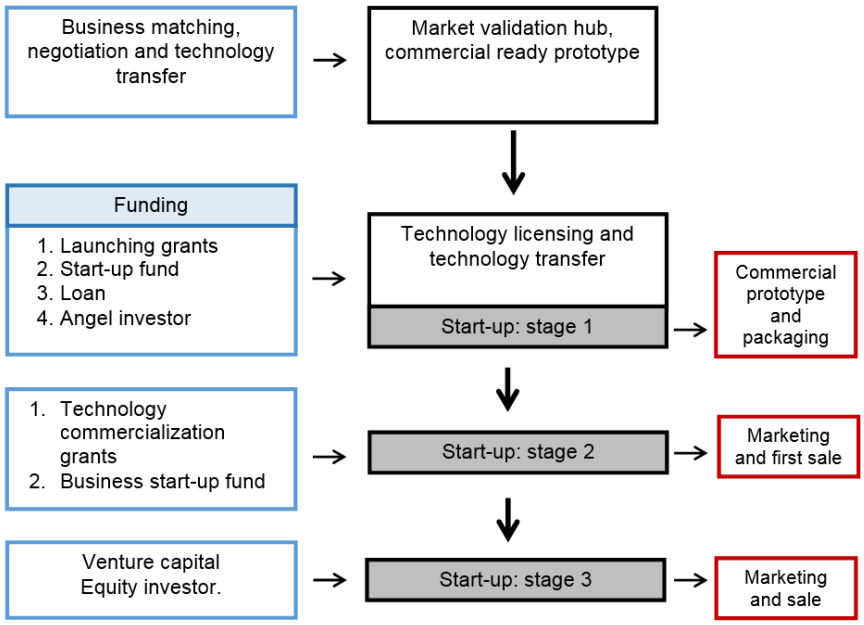

Figure 1. Route of commercialization: funding model at UPM

From the university perspective, technology licensing is often most preferred because of the speed to market, facilitation for optimization of multi-partner relationships, and also to minimize internal financial risk. Many showcases whether alone or by syndication with other organisation have been organized to attract entrepreneurs and investors to participate in commercialization process. Nevertheless, incorporation of start-up spinoff companies is entirely a new approach advocated as a sustainable mode for technology commercialisation. Start-ups can be wholly owned by the university or jointly owned with partners or investors.

UPM, with its prominent strengths in agricultural technology, its rigorous efforts in transforming and translating research output into commercialisation, have helped strengthen the primary university mission of improving and uplifting societal needs. Innovations from the university, particularly in the agricultural field have improved the quality of agricultural practices in Malaysia. There are many examples of useful research output for agriculture applications. One of the most significant commercial products produced by UPM researchers is NDV:V4-UPM vaccine (Figure 2) for Newcastle disease which was recorded back in 1993 (Aini et al., 1990; Aied et al., 2011). A drastic increase in the mortality rate of poultry was observed following Newcastle disease virus infection which resulted in a serious drop of income level. An example of potential use of research output for agriculture application in the field is the use of virus that is non-pathogenic to humans for development of a biological control agent to control wild rat populations that have caused massive losses to rice growers (Loh et al., 2003; Loh et al., 2006). Interestingly, biological materials that resulted from extensive animal research were also used to safeguard human health

Figure 2. Example of commercial products derived from research activities conducted in UPM

(Razis et al., 2006; Vakshiteh et al, 2013; Hani et al., 2014).

Recently, UPM researcher have produced a new cross-breed chicken called 'AKAR PUTRA' characterised by robust growth with bigger body and higher capacity to lay eggs. This new cross-breed of village chicken and red jungle fowl will be of higher value for meat and eggs, an alternative to popular and expensive village chicken. Compared to village chicken, AKAR PUTRA can produce 120 to 200 eggs per year. Moreover, it produced larger eggs compared to village chicken with eggs of 60 grams each compared with village chicken eggs weigh at 45 grams each.

Currently, several researchers are working on clinic-pathology, biochemical and cytokine responses towards *Pasteurella multocida* infection, which is having an apparently high food security concern and commercial potential (Ali et al., 2014; Chung et al., 2015). This research is part of UPM'S effort to bring back buffalo farming to the glory times in the 1960s. Hence, the executive officer has been actively involved in assisting the researcher up to the commercialization stage. Advice and consultancy on consulting arrangements, joint publications with the authoritative body, industrial scientists, and collaborative relationships between university researchers, department of veterinary services have been given to facilitate the formation of formal innovation transfer agreements, all these in a calculated attempt to achieve the singular aim of "Transforming Agriculture Research into Commercialisation".

CONCLUSION

Overall, commercialization of agriculture research is very important and current trends to address food security and safety issues are actively pursued by scientists in an area consisting of environmental efficiency, optimal utilization of raw materials, production efficiency and healthy meat products. The less expensive and more effective technology, products or breed that addresses the need of the 9 billion people in the year 2050 market will generate more commercial value. To achieve this objective, proper management and execution with direct involvement of industrial players and investors via technology licensing and partnerships must be taken into place. The goal is to ensure that the products of world-class science research and innovations can address the needs of industrial players. Once barriers to innovation are halted or removed, research output from universities and institutes shall reach its full potential.

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