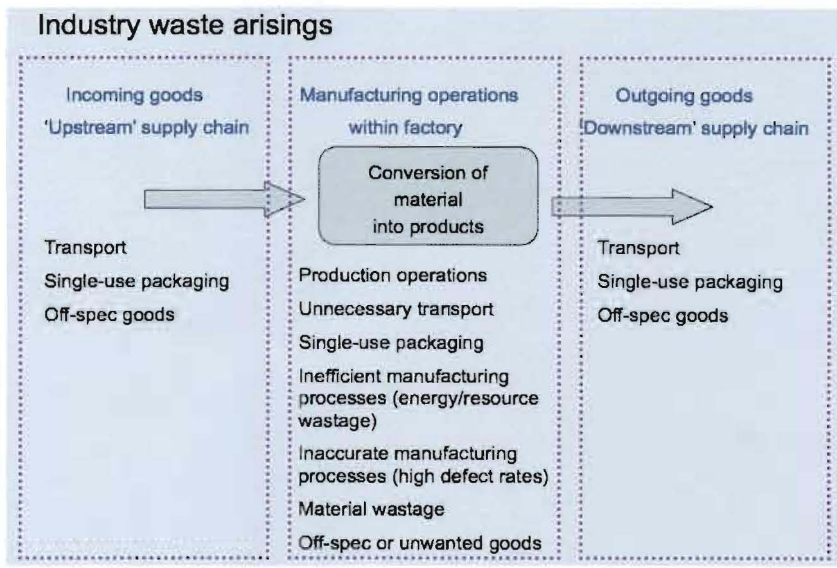
3P10 2012 Crib FINAL CYB

1 (a) The triple bottom line describes the three types of capital on which an operation depends: social, economic and environmental. Tensions arise because companies tend to focus on economic aspects. Profound improvements to social and environmental performance can cost money, although the first steps (e.g. waste reduction, creating a more stable and efficient workforce) can be economically beneficial if done in the right way.

(b) Answers should include mention of waste, use of hazardous substances, energy-efficient manufacturing and factory operations.
Starting the process of gaining ISO14001 accreditation would be generally helpful to the company, but answers should focus on specific short-term improvements.
Waste. Refer to McKinsey abatement curves to identify measures with large environmental impact but low cost.

Production and supply chain wastes:

The single most significant factor from this diagram is likely to be reduction of material wastage from defective products.



'Office' operations within the factory: Biggest environmental cost, and so potential for biggest saving will come from heating efficiency improvement (insulation, smart temperature control systems). Significant lighting efficiency improvements can usually also be made (low energy sources; correct working light levels with timers and automatic sensors). Foster culture of switching off equipment when not being used. Material efficiency improvements from double-sided copying, e-document management leading to reduction in paper copying, recycling. Reduction of waste from old equipment: example of Xerox refurbishment operations.
An important factor for the company is ensuring that environmental awareness is embedded in the culture of the company, by educating the workforce and demonstrating that this is something which is taken seriously by management (e.g. financial incentives). It should be noted that recycling is a good tool for raising awareness of environmental issues, even if the environmental benefits are not of the highest significance.

Hazardous substances: substitute materials should be sought.

Improving sustainability of customers: By making equipment which has built-in features, the company can pass on environmental benefits to its customers. Examples include equipment with minimum operation energy and which automatically switches to low-energy standby mode, machines which default to double-sided copying etc. Xerox is promoting a paper-free environment by selling document management technology which encourages electronic document storage.
Smaller (but psychologically important) improvements can be made by ensuring that any product packaging is minimised, re-usable or at least recyclable.

(c) (i) PSS (leasing machines rather then selling): Manufacturer retains ownership of machines, and sells the service of copying documents whilst taking care of machine maintenance (and in some cases consumables). Potential for waste reduction in the capital equipment comes from: take-back of operational equipment for refurbishment.; design for longer lifetime. A clear business model which is finding favour (again – all early Xerox machines were leased).

(ii) Industrial Symbiosis: Waste from one organisation is used as the an input (raw material, or heat, water etc) for another. Environmental benefits include diverting waste streams from landfill. Financial benefits to both organisations. Potential for new business creation. Applicability to the photocopier business is less obvious: possibilities include finding a partner to receive production waste or post-consumer waste such as toner cartridges.

Examiner's report: Part (a) was generally well answered. In part (b) many answers focused on recycling; some put this in the context of the 'three R's': Reduce, Re-use, Recycle. However, these answers generally omitted that the biggest environmental benefits will come from improving materials efficiency aspects of the manufacturing process (depending on the nature of the business), and on addressing energy costs of the factory (especially space heating). Answers to part (c) were generally quite good, although marks were lost for not making specific reference to the photocopying industry.

2 (a) (i)

PLA and PGA are both polymers (polyesters) that undergo hydrolysis, the breakdown of polymer chain covalent chemical bonds on exposure to water.

Polyester

The most important factor affecting chemical stability of polymers in the body is the chemical nature of the hydrolytically susceptible groups in the polymer backbone. Additional critical factors are:

- the hydrophobic/hydrophilic character of repeat units,
- polymer crystallinity,
- glassy vs. rubbery state (faster reactions in rubbery state),
- geometry (size and surface area to volume ratio) of the device.

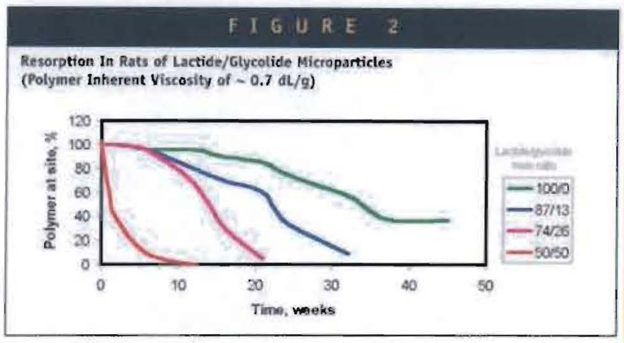
These are all important because of the relative ease of water reaching the hydolytically susceptible groups in the backbone. Water motion through the material is by diffusion and it is slowed by hydrophobic units, by high crystallinity/low porosity and by large diffusion distances in the case of large parts with small surface/volume ratios. Also affecting the degradation rates are the outward diffusion of hydrolysis by-products; if trapped, they can create pH gradients that accelerate hydrolysis in the center of the sample, leading to gradients in the specimen.

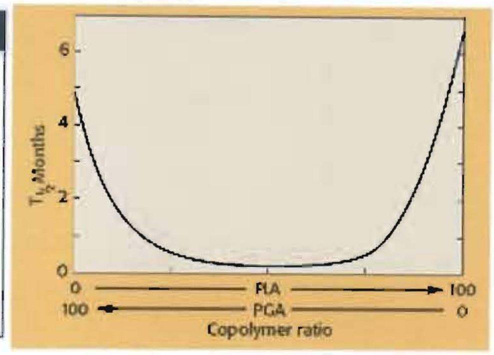
(ii)

Factors that cause differences in bioerosion rates for PGA [poly(glycolic acid)], PLA [poly(lactic acid)] and PGA-PLA co-polymers specifically are discussed next.

PGA and PLA have the same backbone chemistry (ester), but devices made of PGA erode faster than those made of PLA since PLA side chains are more hydrophobic. PLA-PGA blends in the 50:50 composition range are amorphous, while the pure polymers are semi-crystalline. The bioerosion rates for PLA-PGA blends depend on the crystallinity, polymer molecular weight and specimen porosity. Some additional details are in this next image, the key point of which is that amorphous 50:50 blends erode significantly faster than either polymer alone (either of the bottom two plots would satisfy the question in terms of a sketch of the time-scales of co-polymer erosion, either showing the percentage of polymer remaining as a function of time, on the left, or the half-life as a function of composition, on the right). Because this is a continuum, the PGA:PLA ratio can be used to optimize the composition to target a specific degradation rate.

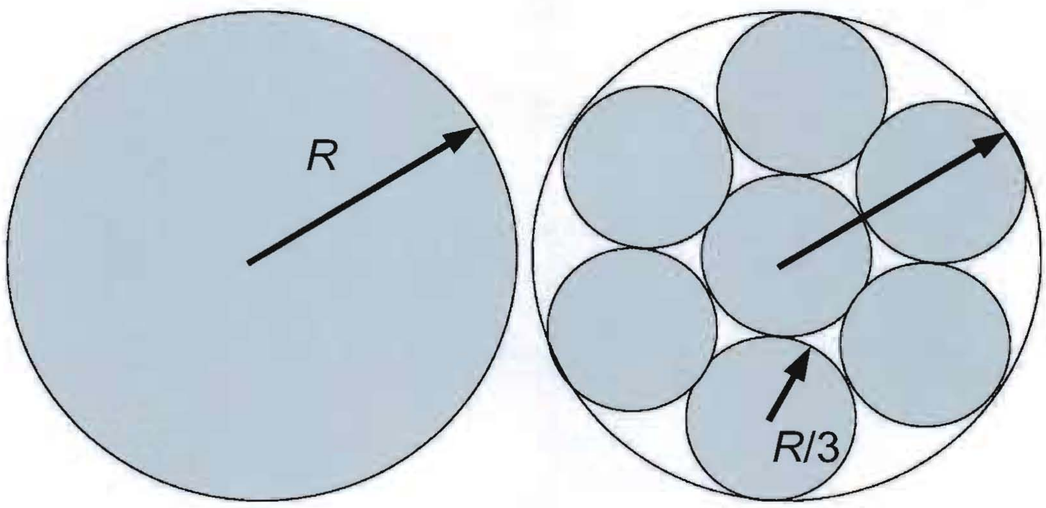
PGA	PLA	Morphology
0-25 mol%	75-100%	Crystalline
25-65%	35-75%	Amorphous
65-100%	0-35%	Crystalline





(b)

A monofilament and multifilament suture of approximately the same size can be compared as follows.



The cross-sectional area of the multifilament is 7/9 the cross-sectional area of a monofilmant with the same overall diameter, so if a surgeon pulls on the suture with the same force, the stress in the multifilament is only 28% greater than that in the monofilament. However, if you consider the bending stiffness, there is a significant and substantial difference. The bending stiffness goes as EI, where $I = \pi R^4/4$. The reduction in bending stiffness for each strand of the multifilament compared with the monofilament is thus $(1/3)^4$ thus making the multifilament far more flexible overall. This makes it easier to loop and knot the multifilament compared with the monofilament.

Multifilament sutures exhibit more friction when being pulled through a tissue (thus could do damage to a delicate tissue, such as the eye) but have knots that tend to be more stable. Monofilaments are less prone to bacterial contamination than multifilaments due to the difference in surface area. Monofilaments would dissolve more slowly than multifilaments, particularly in the instance of surface erosion where the diffusion of water into the material is a limiting factor in the material resorbing. The choice of suture for a particular application comes down to many factors, including doctor preference.

(c)

Tissue engineering involves the seeding of living cells onto a polymeric (or biopolymeric) scaffold. Additional factors, such as growth factors and mechanical forces, can also be included to try and stimulate tissue growth. The cell-scaffold construct can be implanted immediately or grown in a bioreactor for some period of time before being implanted into the body.

In skin graft tissue engineering, the current commercially available products utilize donated (autologous) cells, fibroblasts from fetal foreskins. Two different products are commercially available, Dermagraft and Appligraf.

• Dermagraft matrix is engineering polymeric; Apligraf matrix is a combination of synthetic and natural ECM polymers including bovine collagen
• Dermagraft is a single layer, Apligraf is multiple layers
• Dermagraft is sold frozen and has a 6 month shelf life, while Apligraf is fresh and only has a 5 day shelf life

The four key bioethical principles are:

1. Respect for Autonomy
the patient (or a medical research study subject including someone in a medical implant clinical trial) is a participant in the process (anti-paternalism, the doctor does not act God-like because of his or her education and training in medicine)
2. Justice
there is a fair distribution of scarce healthcare resources, which means that public health systems such as the NHS do not have the option to deprive the many of basic care for specialist care of the few
3. Beneficence
"do good"
4. Non-maleficence
"don't do bad"; a restatement of the Hippocratic canon principle to "first do no harm"

Tissue engineering (TE) is of great interest in regrowing malfunctioning body parts and thus has the potential to **do good**. There is some concern that if the implant does not perform, it could **do harm**; further there are concerns regarding harm done to the cell donor. Because TE is still emerging, there is the opportunity for these therapies to be significantly more expensive than traditional therapeutics, and thus there is a concern regarding **justice** and the fair distribution of scarce healthcare resources. Finally, patients may be unfamiliar with these new technologies, and doctors have a responsibility to offer patients an unbiased set of information about the implants (including the cell source) with the provision of pros and cons allowing for the informed consent of the patient (**respect for autonomy**).

Examiner's report: Most answers demonstrated a good understanding of at least part of the question. Answers to (a) often lacked technical detail. In part (b) many people calculated the ratio of second moment of area of the two filaments, generating an astonishing range of incorrect answers. In (c) knowledge of the details of tissue engineering was very variable, but in some cases excellent. Most candidates showed reasonable understanding of the principles of bioethics, and made some attempt to relate them to skin graft tissue engineering.

3. This question relates to four visits carried out during the academic year. Two in the automotive sector in the Michaelmas term, and two in the FMCG sector in the Lent term. The visits were as follows:
Automotive - Prodrive, Banbury and Jaguar Land Rover, Solihull
FMCG – Premier Foods, Mars Chocolate

(a) Students should be able describe the main practices observed under the categories given.

For example:

	Automotive		FMCG	
	Prodrive	JLR	Premier Foods	Mars Chocolate
Prod processes	Customisation of body parts for motor sport vehicles. Multi-axis CNC machining, EDM. Swarf recycling. Engine building.	Robot welding of steel body panels. Final assembly and trim.	Food processing, making of jams, marmalade, honey and moulded jellies. Mixing, boiling	Chocolate making, chocolate confectionery making: mixing, layering, coating, cooling, polishing, packaging
Prod config	Cellular layout Individual operator responsibility and traceability	Moving track flow line	Batch making of jam. Flow line filling and packaging	Batch mixing (liquid chocolate and coated sweets) Flow line (Mars, Snickers)
Qual systems	High level of testing Engine dynamometer testing Feedback from races	Overhead LED display at lineside. Sample checking of weld quality (1/60 panels) Full body CMM test every 30 mins	Continuous monitoring and sample checking. Visual and taste testing	Continuous monitoring and sample checking. Weight checking and foreign body detection (finished product)

Similarities and differences in practices observed between the various companies should be noted, for example:
Although both in the automotive sector, Prodrive and JLR exhibit very different pactices due to the nature of their products and markets. The former is low volume, bespoke production, serving rally drivers, the latter is high volume, producing luxury 4x4 vehicles for the general public. The focus on the skills of the individual operator at Prodrive leads to a different approach to quality control, based on traceability to the

individual and exhaustive final testing of engines. JLR uses statistically based sampling methods to monitor process and product variation and control quality.
The flow line and batch production processes of the food sector FMCG companies lend themselves to process control oriented quality systems. Data gathering of process conditions is the key to monitoring quality, although sampling of the final product is also carried out. At Mars, finished product is available to staff to eat (test), but has to be signed for tax reasons (so that it is not considered an employment benefit). At Premier Foods tasting of tablet jelly was one of the QC methods.

(b) Discussion of the possible influence of company size, sector and history of ownership could touch on the following issues:

Large companies, multi-nationally based, usually exhibit good practices typical of their sector. Variations may arise through changes of ownership – for example JLR has been successively owned by different companies including British Leyland, BMW, Ford and Tata. Such changes may introduce methods of working specific to the parent company – for example a particular production system or quality routine. Smaller, privately owned companies, for example Prodrive, may exhibit a more idiosyncratic approach to practice, and be heavily influenced, as in this case, by the strong leadership culture established by the founder/owner. Here the emphasis is on an individual's skills, motivation and accountability.
Premier Foods was originally a family business (Chivers) but has since changed ownership several times, including a management buyout, before assuming its current structure. During this process, ownership specific practices diminish, and the observed practice is generic for the types of food products being made.
Mars on the other hand is a privately (family) owned business, with a very strong corporate culture, which influences the approach to all aspects of the operations.
In all cases, appropriate practice will be determined mainly by the product, process and market characteristics. For FMCG companies, this could be characteristic of the sector, since high volumes and flowline production processes are typical, and the need to respond rapidly to customer demand may be another important influence.
Product safety and company liability for the welfare of consumers is a very important factor in the automotive and FMCG sectors when the product is used or consumed by members of the general public. The quality systems deployed will reflect this accountability, giving traceability of the product in case of problems emerging downstream and giving rise to product recall or upgrade.

Examiner's report:
(a) The question covered a lot of territory and a great deal of detail could have been included. The best answers demonstrated good understanding and factual recall of the companies, all the more impressive because half of the company data was gained second-hand from student presentations and discussion sessions. Most candidates were selective in their coverage, often focusing mainly on quality systems. Mention of production processes was sometimes completely lacking, and only a few answers supplied any level of detail of automotive processes in particular.
(b) This section provided the opportunity for more thoughtful analysis of the companies, but answers tended to be disappointingly superficial.