PACKAGING TECHNOLOGY

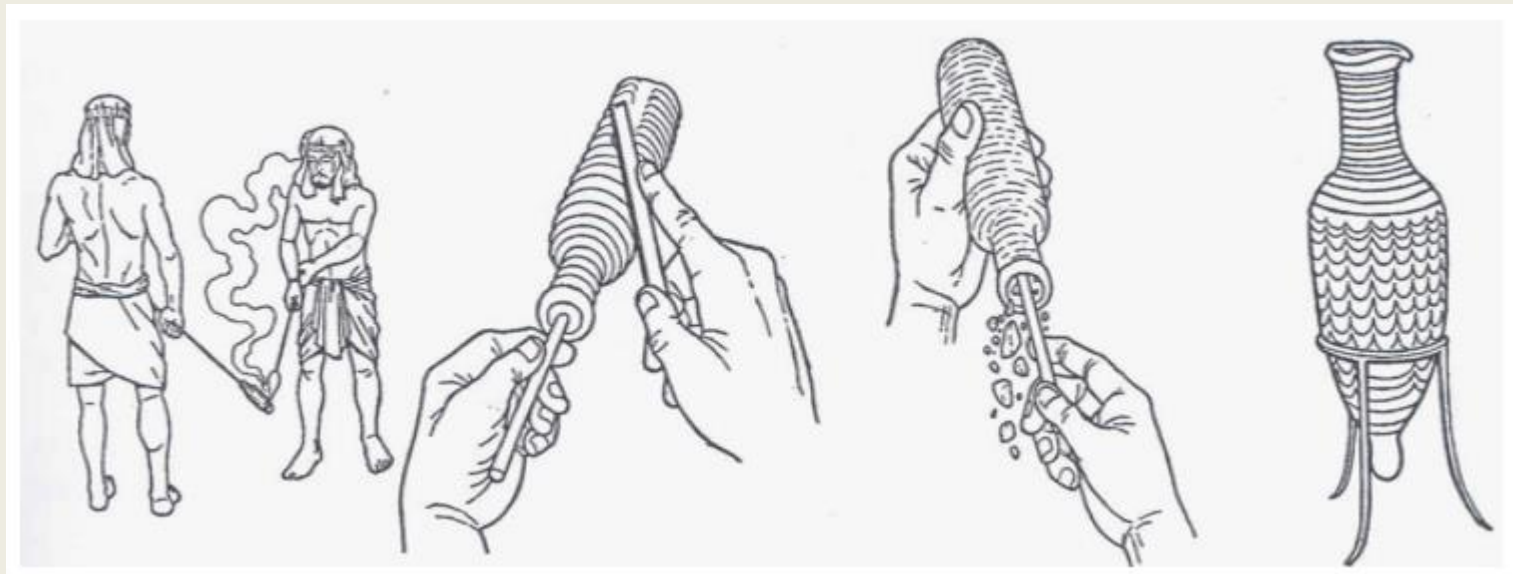
1- PACKAGING FUNDAMENTALS

A History of Packaging

Packaging is best described as «a coordinated system of preparing goods for transport, distribution, storage, retailing and use of the goods»

Packaging has been used in some form or other since the first humans began making use of tools.

Animal skins and hollowed-out fruit husks were used to carry water, and grasses were woven into baskets and panniers to provide a useful way of keeping together and carrying goods.



- Probably one of the first examples of ‘packaging’ to preserve foods was the use of leaves to wrap meat when the tribe was on the move and the source of the next meal was unknown.

- Archaeological evidence dating to 8000 bc shows large wide-mouthed jars being used for grains, salt, olives, oils, etc. The discovery that sand could be fused at high temperatures and made into bottles and jars increased the possibilities for storing and preserving liquids such as oils and perfumes. Both clay pots and glass containers were also used for their decorative qualities, as in the painted amphora given as prizes in the early olympic games from 700 bc .

- As townships and cities developed and men and women became skilled in crafts beyond immediate needs, trade between cities, countries and continents developed, no doubt spurred on by the spirit of exploration which we still see today.

- Thus the concept of using packaging as a convenient means of transporting goods, and to some extent in protecting and displaying them, was established, albeit that this was at the bulk level rather than with any apparent consideration of what the final consumer wanted.

the changing patterns of consumption and their impact on packaging

- A major influence in moving packaging from this bulk level to addressing the individual's needs was the Industrial Revolution, which began in England in the late seventeenth century.
- Foods and basic commodities previously produced and readily available at home, now had to be transported to shops in the cities to be bought by the workers using their hard-earned wages. This increased the demand for barrels, boxes and bags to bring in supplies on a larger scale than had previously been known, and it also brought a need to supply goods in the small quantities now demanded by the workers.

- These new ‘consumers’ lived in relatively cramped surroundings and did not have the large storage facilities previously available on the farms. Thus they needed to make frequent purchases and to carry their goods home, keeping them in acceptable condition as they did so. Goods were often measured out into the purchaser’s own container, but gradually this changed to the shopkeeper pre-packing items such as medicines, cosmetics and tea, and having them available for sale in measured quantities, thus offering the buyer some assurance as to the quality and quantity of the goods. Eventually this pre-packing moved back a further stage from the buyer, to the situation we know today, where most goods are packed at the point of production rather than sale.

Modern Packaging

- **The move from packing goods at the point of sale to packing at the point of production brought about a shift from bulk to consumer packs, which had to survive the journey not just from shop to home, but, more importantly, from factory to shop, a journey which today may span countries and even continents and will include intermediate storage stages en route.**

- **It also gave producers the opportunity to develop their own style of packs to promote their own products, and this has brought us to the modern-day pack.**

Lifestyle changes and their impact on packaging

1. Reduction in the size of the family unit, due to decreased birth rates, increased number of one-parent families and increased longevity. There are now many more single- and two-person households than there were in the 1950s and 1960s and this means a requirement for smaller packs, thus more packaging per kilogram of food.
2. Growth in the number of households in which all adults are in either full-or part-time work, outside of the home. This means less formal meals where everyone sits down together; meals are required at different times, and with minimum preparation. This brings a higher than ever consumer demand for convenience in terms of portion size and food which can be made ready-to-eat at short notice. Ready meals and the packaging formats in which they are presented make a key contribution to meeting this demand.

Lifestyle changes and their impact on packaging

3. Growth in ownership of domestic appliances such as the fridge and freezer has allowed consumers to buy larger quantities of 'fresh' foods, which are expected to remain in good condition for prolonged periods of time. The development of the low-cost domestic microwave oven brought with it a requirement for microwave-suitable packaging.
4. More disposable income means more money to spend on food, especially luxury food and drink.
5. More international travel and exposure to other cultures, leading to interest in 'ethnic' foods, but with minimal preparation time.

the effects of globalisation and modern retailing

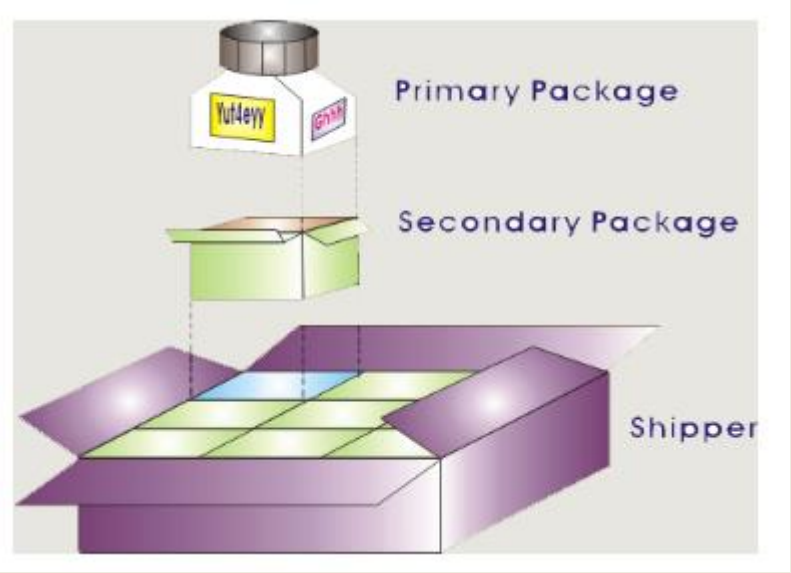
As well as the societal changes mentioned above, changes in the way businesses operate also strongly influence the need for and the types of packaging used.

1. The globalisation of manufacturing, with products being shipped over long distances and through different climatic conditions places strong emphasis on packaging to provide protection against likely hazards.
2. Modern supermarkets demand fast stock replenishment with a minimum of manual effort. This has brought a requirement for secondary packs which can 'double up' as shelf-ready display packs, with no handling of the individual primary packs.
3. Modern supermarkets also demand rapid service at the checkout, and here the ubiquitous bar code provides a quick and reliable means of identifying the product and its price. Importantly, this data is also used for stock control purposes, often linked to automatic ordering to replenish supplies.

The different levels of packaging: primary, secondary and tertiary

Primary packaging includes not just the materials in direct contact with the product, but all of the packaging which surrounds the product when the consumer takes it home. For a multipack of crisps, for example, the primary packaging will be the individual bags and the large bag into which the separate packs are packed. A useful way to define primary packaging is to think of it as all the packaging which eventually finds its way into the domestic waste stream, once the product is used up.

Secondary packaging is used to group packs together for ease of handling. In the example above of the crisps, several multipacks are packed into printed corrugated cases. The case is the secondary packaging. Other examples of secondary packaging are shrink-wrap film, and the corrugated board and thermoformed plastic trays used for shelf-ready packaging.



Tertiary packaging is used to collate secondary packs for ease of transport. One of the most common forms of tertiary packaging is the pallet, along with stretch-wrap film and a label, to secure the secondary packs to the pallet and provide a ready means of identification. Roll cages and crates are also examples of tertiary packaging.

PACKAGING FUNCTIONS

To understand the functions of the pack and to ensure that they are adequately met, it is essential to define the product in terms of **its nature, critical properties and value**. This should always be the starting point; packaging does not have a 'life' of its own and without a product it has no reason to exist.

The packaging designer/specifier needs to work closely alongside the product developer to gain a full understanding of the product and what can cause it to deteriorate to the point of being unacceptable.

Function 1: Containment

Properly designed, constructed and sealed packs provide complete containment for the contents, preventing unsightly or dangerous leakage, or loss of parts.

This containment must be assured throughout the expected life of the product, including the numerous handling stages from the end of the packaging line to the final consumer use. Containment also means keeping a number of different or the same items packed together, and this applies to primary, secondary and tertiary packs.

- packs of different varieties of crisps assembled into one bag, or the various parts needed in a hair colouring ‘kit’ such as colour, developer, gloves and comprehensive instruction sheet
- filled bottles of shampoo collated in a display tray
- stretch wrap film used to secure goods to a pallet.

Examples of containment failure

Pack type	Potential failure points/ mode of failure	Typical possible causes
Cartons	Glue seams split	Wrong adhesive for board and conditions of use; poor control of adhesive application conditions
	Tuck-in flaps work loose, tear	Wrong board weight for the weight of the product; poor cutting and creasing of the carton
Bottles/caps	Leakage at neck, misalignment of cap	Dimensional inaccuracies in bottle and/or cap finish; wrong cap application force; wrong wadding material
	Leakage at mould part line and/or injection point (plastic)	Poor control of moulding conditions
Sachets	Leakage in seal areas	Wrong sealing layer; poor control of sealing conditions; product in seal area
	Leakage in body of sachet	Puncture by product or by external means
Tubes	Leakage at neck, misalignment of cap	Dimensional inaccuracies in tube and/or cap finish; wrong cap application force; wrong dimension of orifice
	Leakage at base of tube	Wrong sealing layer; poor control of sealing conditions; product in seal area

Function 2: Protection

Protection means the prevention/reduction of physical damage to the product, during all stages of its life. This includes manufacture and packaging operations, storage and handling in warehouses, transport to the merchant, distributor or store for sale, display, and moving to the final usage point.

It also includes storage and use of the product, e.g. in a kitchen, garage or garden, and any other handling operations which the final user may be reasonably expected to carry out on the product.

Damage can occur at any of these handling stages, although most physical damage happens in the warehousing and distribution environment, due to dropping (from pallets, and during order picking and transit), jolting, vibration (in vehicles), compression (when stacked in warehouses) or puncturing (often due to use of poor quality pallets). Damage can also result from environmental factors such as dust, dirt, birds, insects and rodents.

Typical hazards in the supply chain, their causes and effects

Hazard	Causes	Possible effects
Shock	Falls from conveyors, pallets, vehicles, possibly due to poor stacking; shunts due to irregular movement along conveyors; drops due to manual handling; impacts in transit due to driving over poor road surfaces	Breakage; deformation
Vibration	Vibration occurs naturally in all types of transport. In road transport the effects are enhanced over the rear axle of the vehicle, and by any imbalance in the load. Irregular road surfaces also increase vibration	Breakage; scuffing; product separation and/or settlement; loosening of screw caps; garments falling from hangers
Compression – static	Stacking in storage, made worse by damp conditions	Breakage; crushing; load collapse
Compression – dynamic	Clamp truck pressure; severe vibration during transport	Breakage, crushing, stack resonance

Puncture	Poor quality pallets, bad handling practices	Breakage; product spoilage; load collapse
Changes in relative humidity	Loads left outside; goods stored in damp warehouses, or where climatic conditions are not controlled; goods shipped via and to different climates	Product spoilage, e.g. corrosion; packaging failure, e.g. damp corrugated board cases
Changes in temperature	As above	Product spoilage; drying out of paper/board materials;
Exposure to light	Retail display	Fading of product and/or pack; product spoilage, e.g. rancidity
Insects, rodents, birds, dust, dirt	Goods stored in warehouses not cleaned or treated for pest control, or where doors/windows are left open or badly fitting	Product spoilage due to poor hygiene; contamination of product and pack
Pilferage and tampering	Goods exposed to uncontrolled personnel access; display on shelf	Loss of products; damaged packs and products; contamination; counterfeit products

The key steps to follow to decide what type of packaging will provide the product with the appropriate level of protection are:

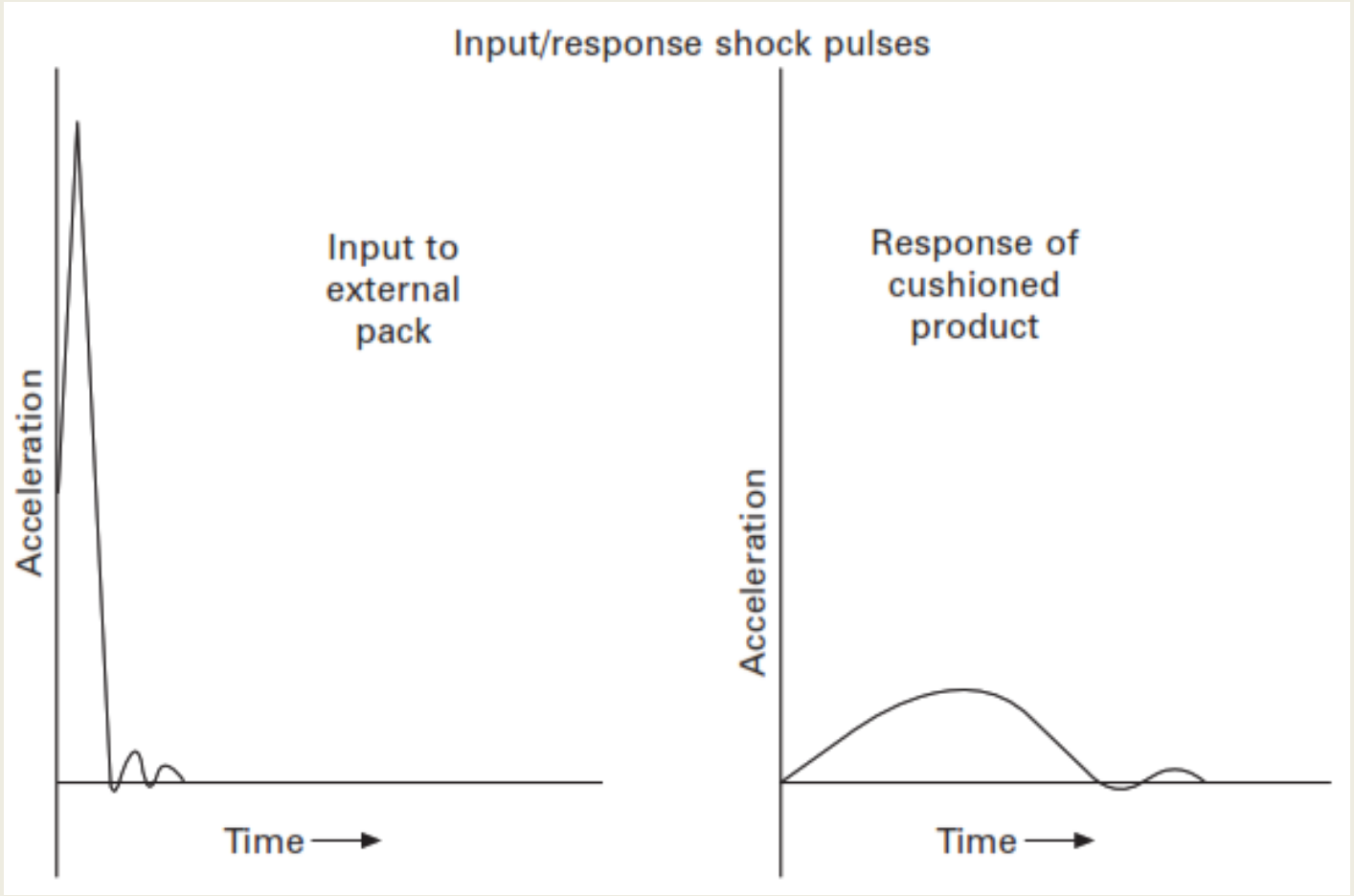
1. define the product
2. define the environment to which the product is likely to be exposed
3. investigate the properties (including cost) of available protective packaging materials

Ways of minimising the effects of the common hazards

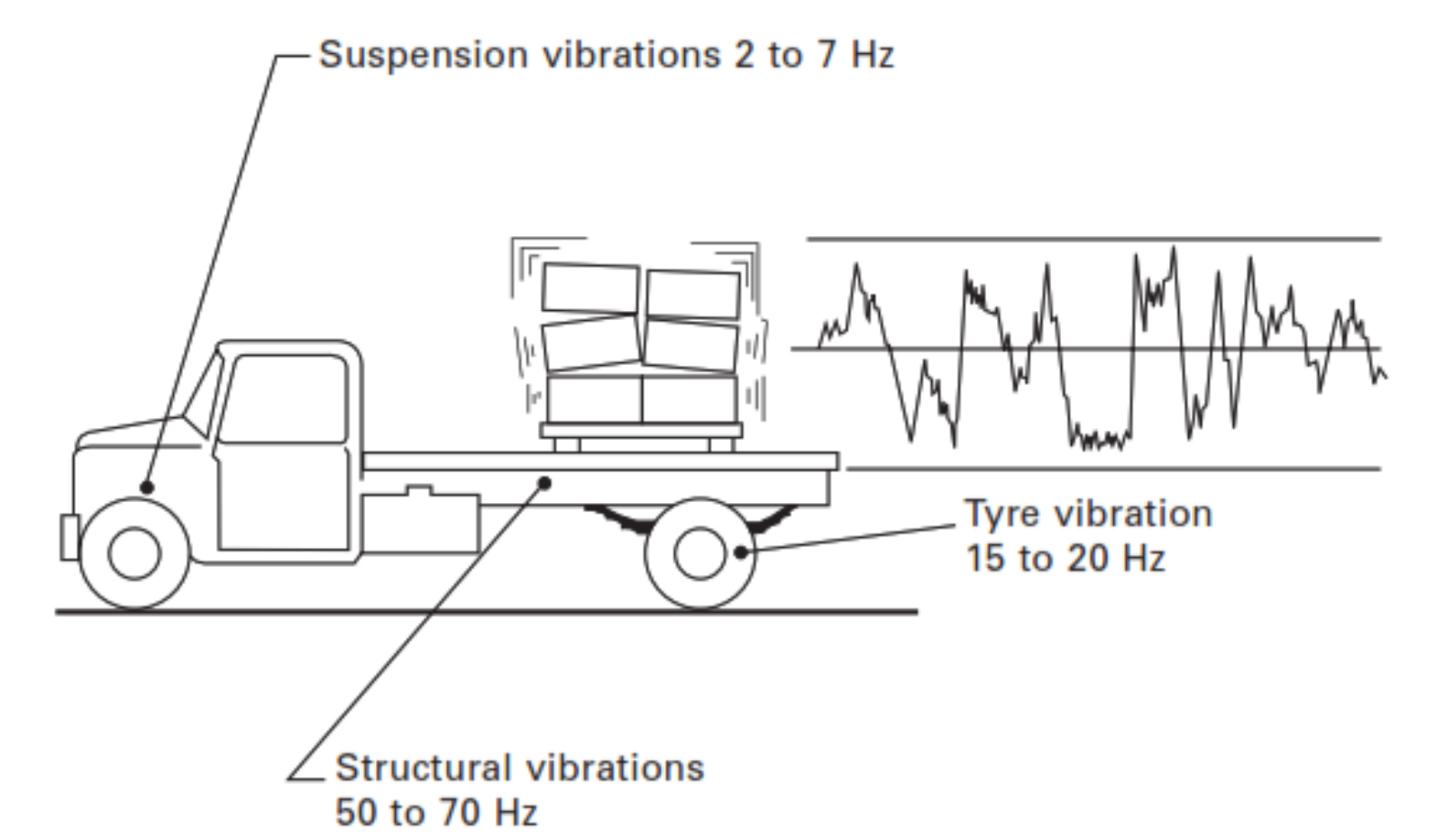
Hazard	Minimising the effects	
Shock	Reduce the amount of manual handling	
	Use cushioning materials, such as:	Polyethylene foam Expanded polystyrene Loose fill polystyrene chips Bubble wrap Compressed paper Moulded pulp Corrugated board
Vibration	Reduce product/pack movement:	Use tight shrink wraps Use accurate dimensions when sizing packaging Use pallet adhesives to prevent case movement
	Reduce contact points:	Good design of containers Label recess areas
	Protect surfaces:	Scuff resistant lacquers and film coatings
	Isolate the vibration	Use appropriate cushioning, or special 'air ride' vehicles, as used for susceptible products such as electronics

Compression	Good design of all levels of packaging	Design as a total pack, primary, secondary and tertiary
	Selection of pallet stacking pattern	Consider pallet stability and the likely stacking height
	Good storage conditions	Monitor temperature and humidity, especially when using paper/board
Puncture	Good pallet quality	Specify and monitor
	Good handling practices	Operator training
Changes in relative humidity	Operate good handling and storage practices throughout the supply chain Monitor relative humidity and introduce controls if necessary Use moisture-resistant materials/coatings	
Changes in temperature	Operate good handling and storage practices throughout the supply chain Monitor temperature and introduce controls if necessary Use temperature-resistant materials, e.g. expanded polymeric foams	
Exposure to light	Use opaque packaging	
Insects, rodents, birds, dust, dirt	Operate good standards of hygiene, including pest control, throughout the supply chain Carry out regular inspections to check on compliance	
Pilferage and tampering	Consider tamper evidence features in all levels of packaging Consider need for surveillance Consider anti-counterfeit measures	

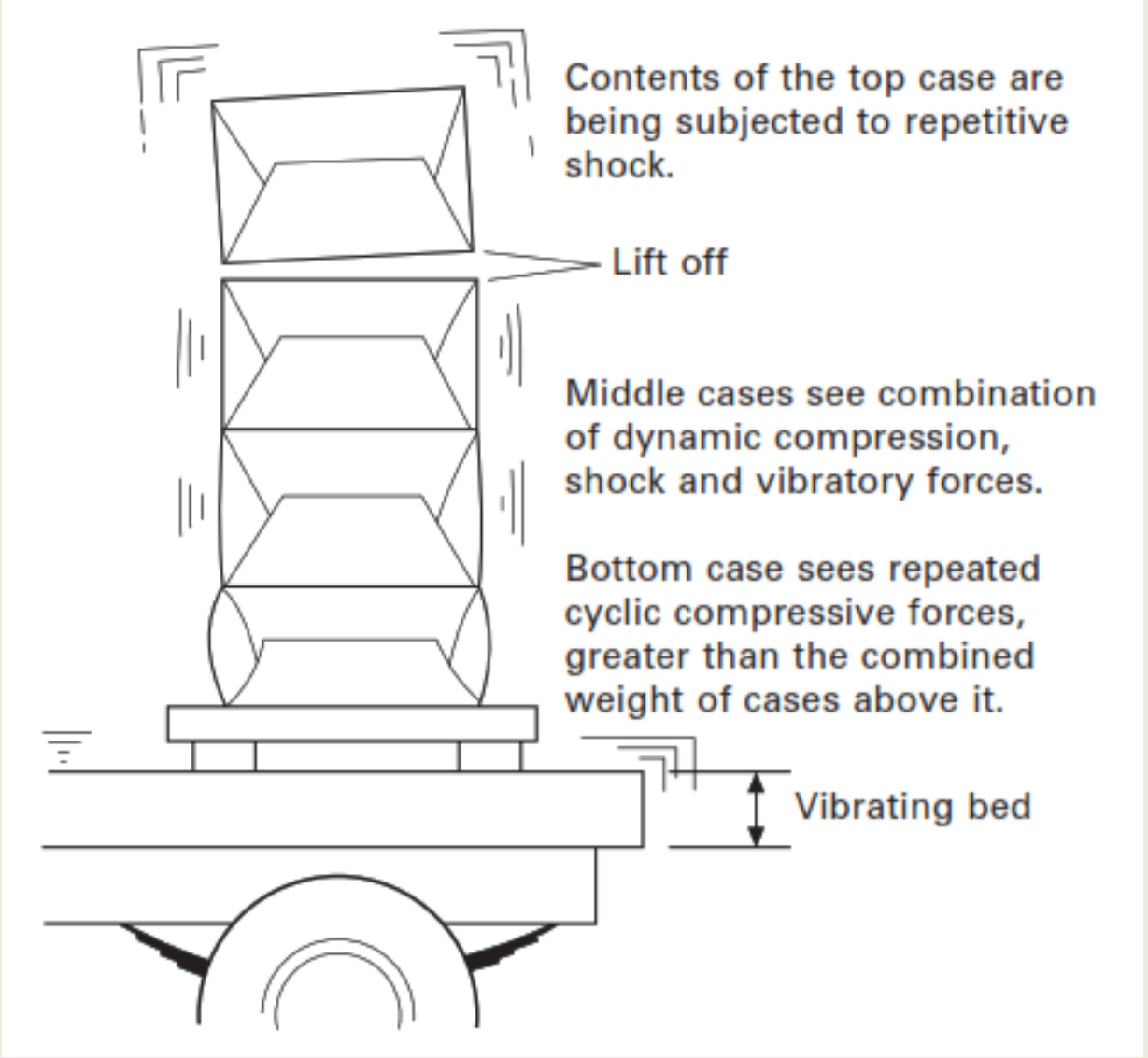
Effect of cushioning on shock.



Typical sources of vibrations in road vehicles.



Stack resonance on a vehicle.



Mapping the journey:

Hazard	Data
Shock	What level and skill of labour is available? To what extent is manual handling used? How many times is the pack handled as: • primary pack • secondary pack • tertiary pack What is the most likely drop height?
Vibration	What methods of transport are used? What are the most likely vibration frequencies experienced?
Compression	Are pallets always racked, or is block stacking likely? What is the maximum top load during storage? Are loads evenly distributed? What is the most likely maximum dynamic load?
Pressure	What are the likely altitude and pressure changes? This is important if air freight is to be used
Environment	Will the product be stored outside? What is the range of humidity and how rapidly does it change? What is the range of temperature and how rapidly does it change? What are the likely conditions of cleanliness? Are the goods likely to be stored in poorly managed conditions and is security a potential problem?

Function 3: Preservation

Preservation means the prevention/reduction of changes due to biological and chemical hazards, which would lead to product spoilage.

The objective of preservation is to extend the shelf life of a product. This section applies mainly, but not exclusively, to the food, drink, pharmaceutical and cosmetic industries.

According to the Institute of Food Science and Technology, 'shelf life' is defined as the time during which the product, when stored at the recommended conditions, will:

- remain safe;
- be certain to retain desired sensory, chemical, physical and microbiological characteristics;
- comply with any label declaration.

When considering the preservation function of packaging, it is important to recognise that whilst packaging can and does contribute to shelf life, it cannot overcome inherent product problems; if the product is unsafe at the point of packing, it is likely to remain unsafe inside the pack.

Within the limitations mentioned above, to determine the optimum packaging required to extend shelf life, we need to define the product in terms of what will cause it to deteriorate, i.e. what is the spoilage mechanism. We then need to understand what process (if any) will be used to prevent/delay spoilage and the extent to which this will affect the packaging used, and therefore determine its key properties.

- Defining the spoilage mechanism of a product is part of the research and development stage of the product.
- Product spoilage, and therefore shelf life is determined by microbiological, physical or chemical factors, depending on the product, the process, the packaging and the storage conditions.
- Broadly, spoilage due to microbiological spoilage is referred to as biotic spoilage, and that due to physical and/or chemical factors is known as abiotic spoilage.

Biotic spoilage is caused by microorganisms (bacteria, moulds, yeasts) which may render a product unacceptable in appearance, taste, smell and effectiveness, or be toxic and cause sickness. Different organisms have preferred conditions for growth and adverse conditions in which they will not propagate, and this is the basis of product preservation systems. The conditions to be considered are as follows:

- *Temperature*. Microorganisms may be classified by their preferred reproduction temperature:
  - psychrophiles grow best in fairly cool conditions (10–20°C);
  - mesophiles grow best at 20–40°C;
  - thermophiles prefer temperatures in the range 40–60°C.

  Note, however, that there is considerable variation within each classification and these temperature ranges are not exact.
- *Humidity*. Microorganisms need water in which to grow and as a general rule, the lower the level of available water in a product, the less likely it is that microorganisms will propagate.
- *Acidity*. Microorganisms have an optimum pH level at which they will grow. In general, moulds and yeasts grow best in acidic environments and bacteria grow best in neutral to slightly alkaline conditions, although there are exceptions to this.
- *Presence of oxygen*. Some microorganisms need oxygen to propagate and are known as aerobes, while others cannot propagate in the presence of oxygen and are known as anaerobes. Some can propagate in either oxygen or oxygenless environments. In general, moulds and yeasts need oxygen to propagate, although some yeasts grow in anaerobic conditions.
- *Nutrient source*. All microorganisms need a nutrient source, although their needs vary greatly. Nitrates, lactates and amino acids are typical nutrient sources found in foodstuffs.

Abiotic spoilage refers to the chemical or physical changes brought about by external factors such as oxygen, moisture, light, temperature, loss/gain of volatiles, e.g.:

- oxygen, causing rancidity in fats, creams and oils
- loss of moisture causing drying out and hardening of bread, lipstick, pastes, etc.
- gain of moisture causing lumping of powders and loss of crispness of cereals and biscuits; corrosion of metal products and packs also comes into this category
- light causing colour fading or oxidation
- excessive heat causing drying out
- excessive cold causing undesirable freezing e.g. emulsions
- loss of volatiles such as some of the oils in tea, which affects its taste
- gain of volatiles which make a product taste odd, e.g. chocolate stored next to highly fragranced soaps, without an adequate barrier in the packaging will quickly pick up the volatiles in the soap and taste soapy. Unacceptable volatiles can also be picked up from printing inks and adhesives, due to high levels of retained solvent.

PRESERVATION PROCESS

The basic principle of product preservation processes is to address the cause(s) of spoilage, and then to use appropriate packaging and storage conditions to maintain the product in its desired state. Referring back to the causes of biotic spoilage listed in the previous section, it can be seen that these can be addressed by:

- changing the temperature to destroy microorganisms, or impede their growth, using heat (pasteurisation, sterilisation) or cold (chilling, freezing).
- reducing the water activity (A_w) in a product. A_w is a measure of the amount of available water in the product and lowering this limits microorganism growth. Methods of reducing A_w include drying (which removes water) and the addition of salt or sugar (which 'ties up' the free water).
- changing the acidity level, e.g. pickling using vinegar.
- varying the oxygen level, which can be done by vacuum packaging (where the product is packed and then the air is evacuated from the pack before sealing) or by changing the gaseous mixture around the product (modified atmosphere packaging

Summary of the common preservation methods and associated packaging requirements

Preservation	Method	Packaging properties
Cooling	Chilling	Able to withstand storage temperature without deterioration such as cracking or loss of print Odour barrier May also require light barrier Toughness, puncture resistance to withstand handling on display Pack should fit standard domestic refrigerator
	Freezing	Able to withstand blast freezing and storage temperatures without deterioration, as above Appropriate moisture barrier, to prevent freezer burn Odour barrier May also require light barrier Toughness, puncture resistance to withstand handling on display

Preservation	Method	Packaging properties
Heating	Pasteurisation, hot filling Sterilisation (canning and retorting)	Able to withstand temperature and pressure changes during heating process Water resistance Toughness, puncture resistance to withstand physical handling during process
Drying	Air drying, heat drying, salting	Appropriate moisture barrier Resistance to chemicals used
Chemical Preservation	Pickling/other chemicals Oxygen scavengers	Resistance to chemicals used
Varying oxygen levels	Vacuum packaging MAP Oxygen scavengers	Gas barrier Puncture resistance
Irradiation		Resistance to ionising radiation

Summary of packaging requirements to reduce/prevent abiotic spoilage

Spoilage mechanism	Packaging properties
Oxygen	Appropriate gas barrier
Loss of moisture	Appropriate moisture barrier, related to the equilibrium relative humidity of the product
Gain of moisture	Appropriate moisture barrier, related to the equilibrium relative humidity of the product May require moisture permeable pack
Light	Appropriate light barrier
Heat/cold	Insulation Importance of control of storage and handling conditions
Loss of volatiles	Appropriate gas barrier Appropriate chemical resistance
Gain of volatiles	Free from taint and odour

Good pack design will determine how easy/difficult it is to dispense the desired amount of product and this is especially important for potentially ‘difficult’ products such as nail enamel, shoe polish, syrups, motor oil, viscous adhesives, paint, etc. If the pack offers clean and safe delivery, with no mess or loss of product, it can provide the all-important competitive edge in a crowded market. Just some examples of consumer convenience are:

- the ability to dispense and direct the required amount of product using aerosols, natural pump sprays, special nozzles on tubes, brush applicators, etc.;
- easy product access from tubes and squeezable bottles;
- easy-open features such as tear-tapes in film wraps or 'tear here' cuts in sachets;
- easy-open and reclose features such as flip-top closures on sauces and shampoos;
- packs which collate, for example, five individually-wrapped snacks into one pack which is easier to handle and store in the cupboard than single packs;
- boil-in-bag and heat-in-tray foods, which mean no dirty saucepans;