ENR212 Lecture 4 Slides and Notes

Slide 1

Hello, everyone, and welcome to lecture summary 4 of Manufacturing Processes. (This lecture works through material covered in Chapter 10 of the textbook.)

In this lecture summary, we will introduce the fundamentals of metal casting, including the pros and cons of metal casting, classifications, mould structure, casting processes, and the intrinsic problems of metal casting design.

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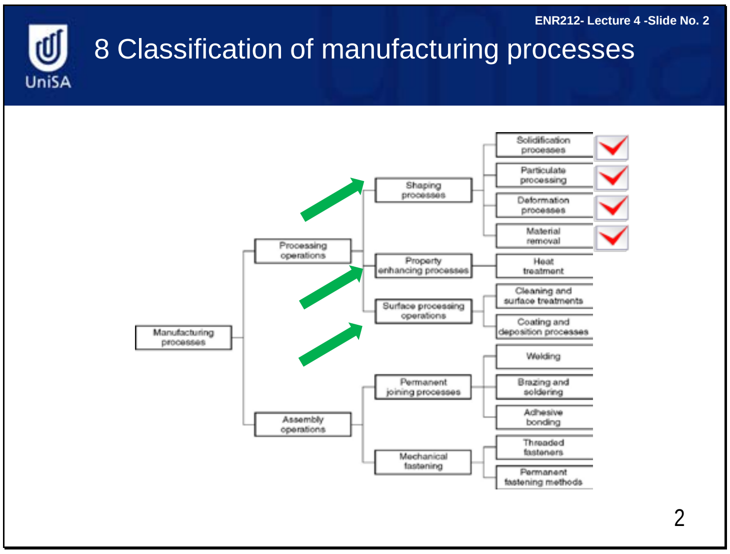

First, let's review the classification of manufacturing processes. Manufacturing processes comprise processing operations and assembly operations. In processing operations, making a part shape is essential. Once the part shape is made, the properties and surface finish can be improved. So processing operations include shaping processes, property enhancing processes, and surface processing operations. Shaping processes comprise solidification processes (where the starting material is liquid or a metal melt), particulate processes (where the starting material is particles), deformation processes (where the starting material is a solid piece of material) and material removal processes (whose purpose is to remove extra material to achieve the desired accurate geometry).

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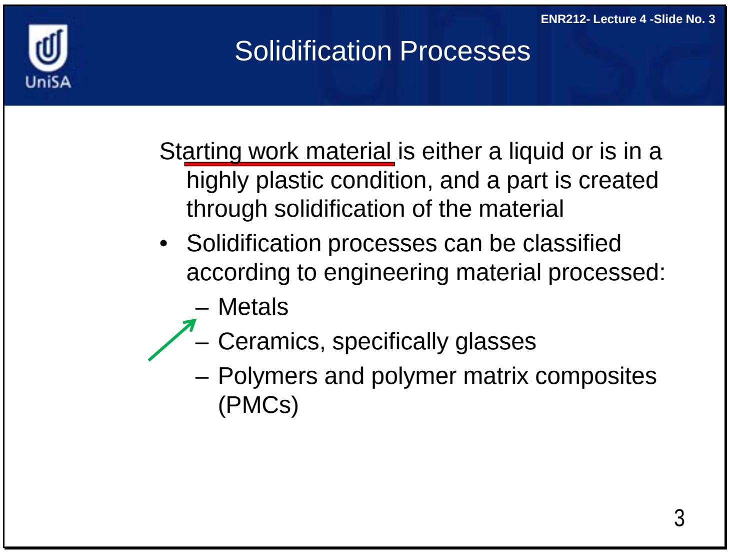

In a solidification process, the starting work material is either a liquid or is in a highly plastic condition, and a part is created through solidification of the material. According to the materials processed, the solidification processes can be classified into: metal casting for metals, ceramics solidification processes, and thermal plastic moulding for polymers.

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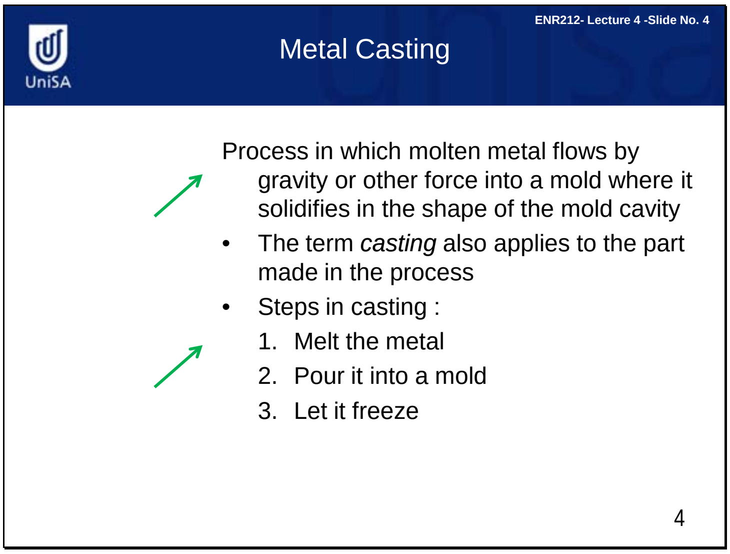

Casting is a process in which molten metal flows by gravity or by other types of force into a mould, where it solidifies in the shape of the mould cavity. The term casting is also applied to the part that is made by this process. The principle of casting seems simple: just melt the metal, pour it into a mould, and let it cool and solidify. However, there are many factors and variables that must be considered in order to accomplish a successful casting operation.

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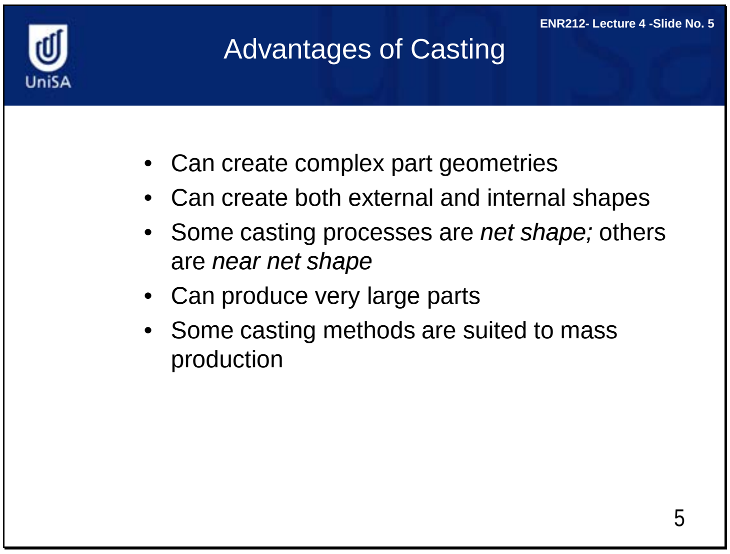

Casting can be used to create complex part geometries, including both external and internal shapes.

Some casting processes are capable of producing parts to net shape. No further manufacturing operations are required to achieve the required geometry and dimensions of the parts. Other casting processes are near net shape, for which some additional shape processing is required in order to achieve accurate dimensions and details.

Casting can be used to produce very large parts, such as castings weighing more than 100 tons. The list of large parts made through casting includes engine blocks and heads for automotive vehicles, machine frames, railway wheels, pipes, pump housings, etc. Small parts include dental crowns, jewellery, statues, frying pans, etc.

Some casting methods are quite suited to mass production.

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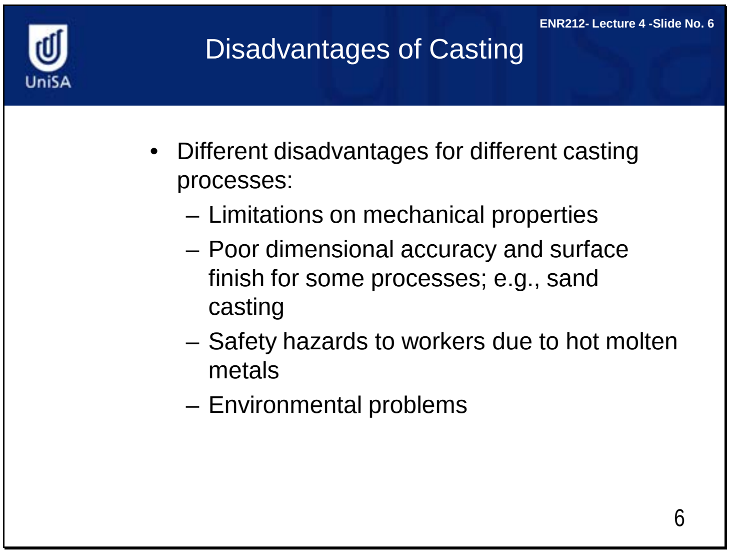

There are disadvantages associated with casting. These include limitations on mechanical properties, porosity, poor dimensional accuracy and surface finish for some casting processes, safety hazards to humans when processing hot molten metals, and environmental problems.

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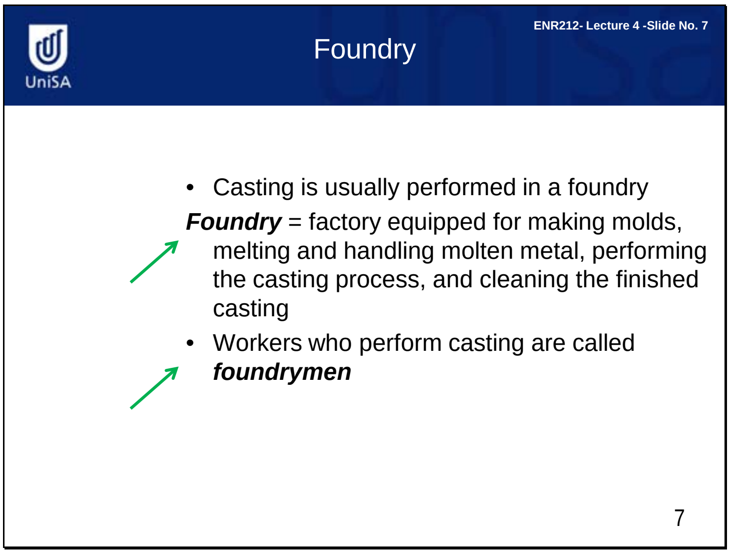

Casting is usually carried out in a foundry. A foundry is a factory equipped for making moulds, melting and handling metal in molten form, performing the casting process, and cleaning the finished casting. The workers who perform the casting operations in these factories are called foundry men.

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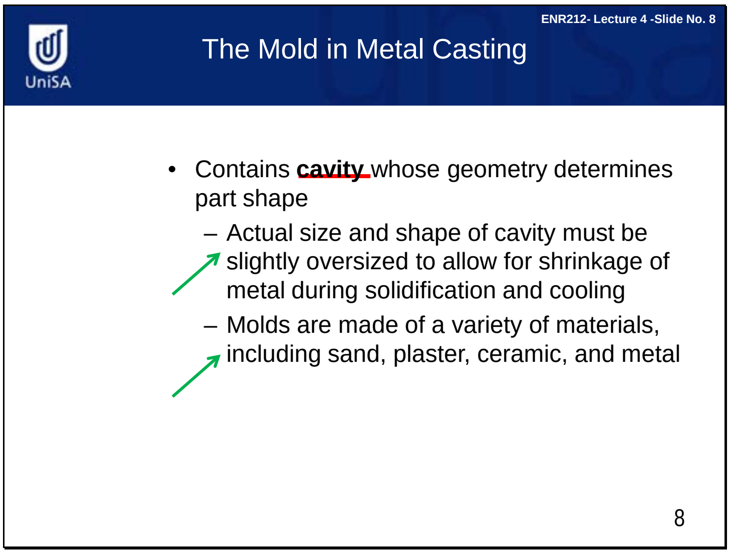

The mould in metal casting contains a cavity whose geometry determines the shape of the cast part. Since the density for a given metal in a solid state is higher than its density in a molten state, the actual size and shape of the cavity must be slightly oversized to allow for the shrinkage that occurs in the metal during solidification and cooling. Different metals undergo different amounts of shrinkage, so the mould cavity must be designed for the particular metal to be cast if dimensional accuracy is critical. The moulds are made from a variety of materials, including sand, plaster, ceramic, and metal.

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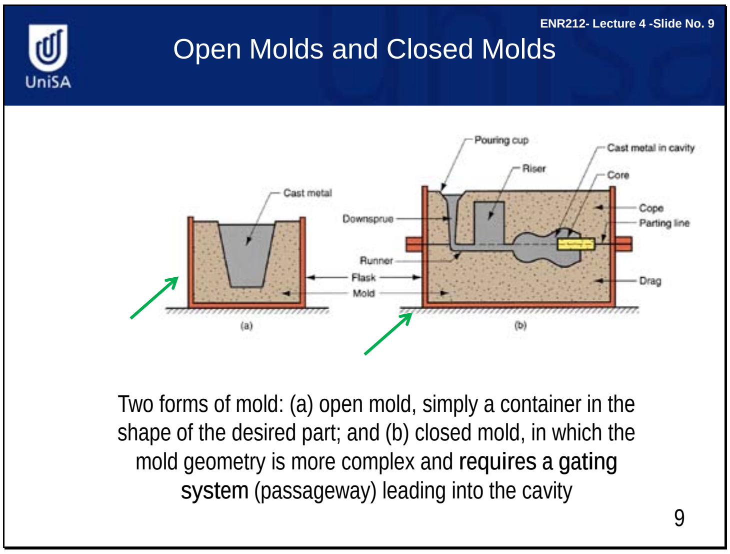

To accomplish a casting operation, the metal is first heated to a temperature which is high enough to completely transform it into a liquid state. It is then poured, or otherwise directed, into the cavity of the mould. In an open mould, the liquid metal is simply poured in until it fills the cavity. In a closed mould, a passageway, called the gating system, lets the molten metal flow from outside the mould into the cavity.

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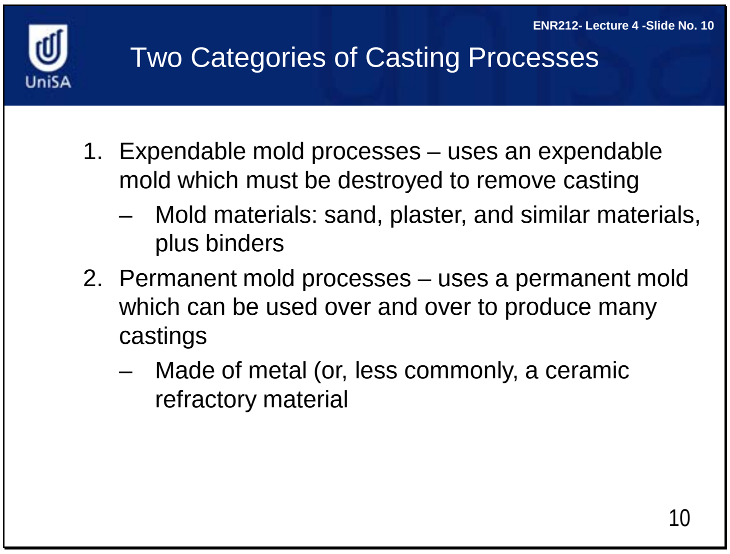

There are two categories of casting processes: expendable mould processes and permanent mould processes.
An expandable mould means that the mould in which the molten metal solidifies must be destroyed in order to remove the casting. These moulds are made out of sand, plaster, or similar materials. They maintain their form by binders of various kinds.

By contrast, a permanent mould is one that can be used over and over again to produce many castings. It is made of metal that can withstand the high temperatures of the casting operation.

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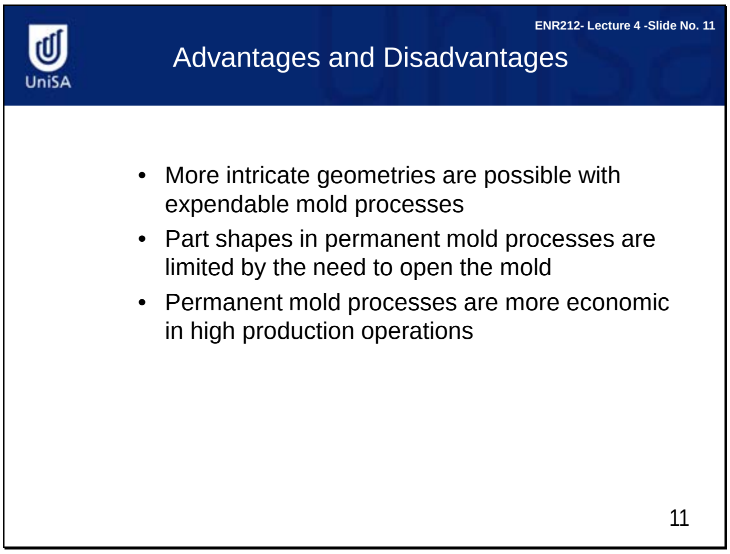

If we compare expandable processes with permanent mould processes, we can see that more sophisticated casting geometries are generally made with the expendable mould processes.
Casting part shapes by using permanent mould processes is made more difficult because of the need to open the mould. On the other hand, some of the permanent mould processes have certain economic advantages in high production operations.

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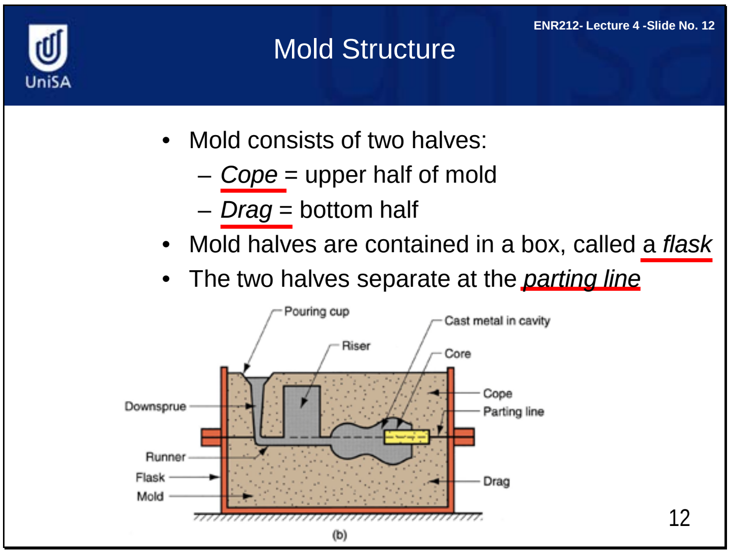

A mould consists of two halves: the cope and the drag. The cope is the upper half of the mould, and the drag is the bottom half.

These two mould parts are contained in a box, called a flask, which is also divided into two halves, one for the cope and the other for the drag.

The two halves of the mould separate at the parting line. This figure is one of the final exam topics. You will be given this figure and will be asked to give the names of some of the parts.

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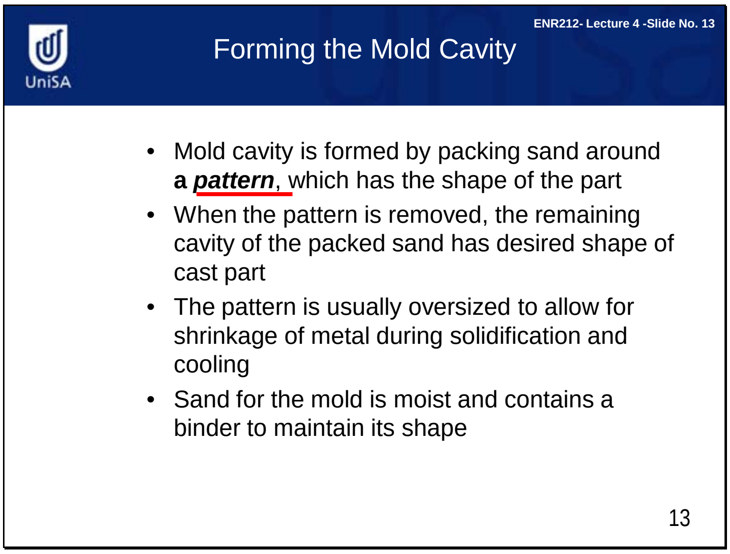

In metal casting, the mould cavity is formed by means of a pattern, which is made of wood, metal, plastic, or other material which has the shape of the casting. The cavity is formed by packing sand around the pattern, so that when the pattern is removed, the remaining void has the desired shape of the cast part. The pattern is usually made oversized to allow for shrinkage of the metal as it solidifies and cools. The mould is usually made of sand, which is moist and contains a binder to maintain its shape.

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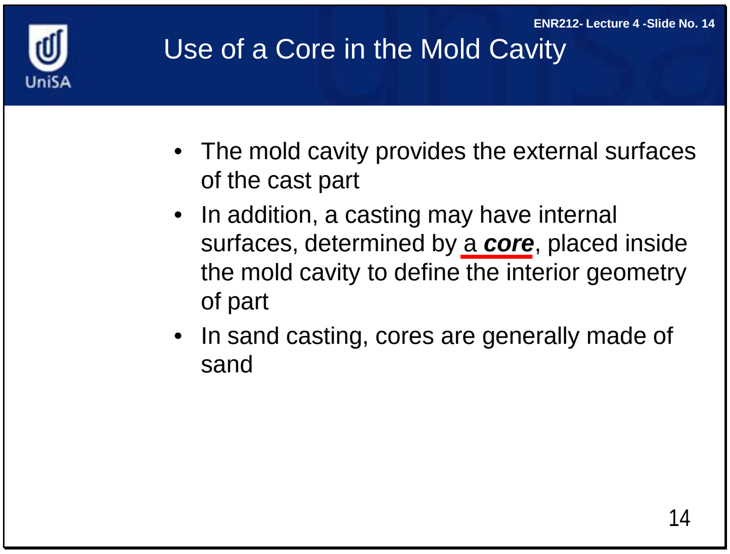

The cavity in the mould provides the external surfaces of the cast part. In addition, a casting may have internal surfaces. These surfaces are determined by means of a core, which is placed inside the mould cavity to define the interior geometry of the part. In sand casting, cores are generally made of sand, although other materials can be used, such as metals, plaster, and ceramics.

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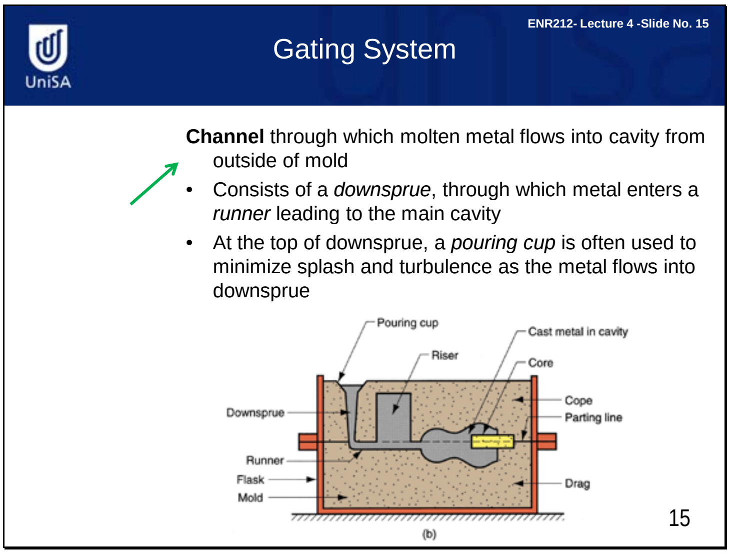

The gating system in a casting mold is the channel, or network of channels, by which molten metal flows into the cavity from outside the mould.
As shown in the figure, the gating system typically consists of pouring cup, downsprue and runner. In this system, the metal enters a runner that leads into the main cavity. A pouring cup is often used to minimize splash and turbulence as the metal flows into the downsprue.

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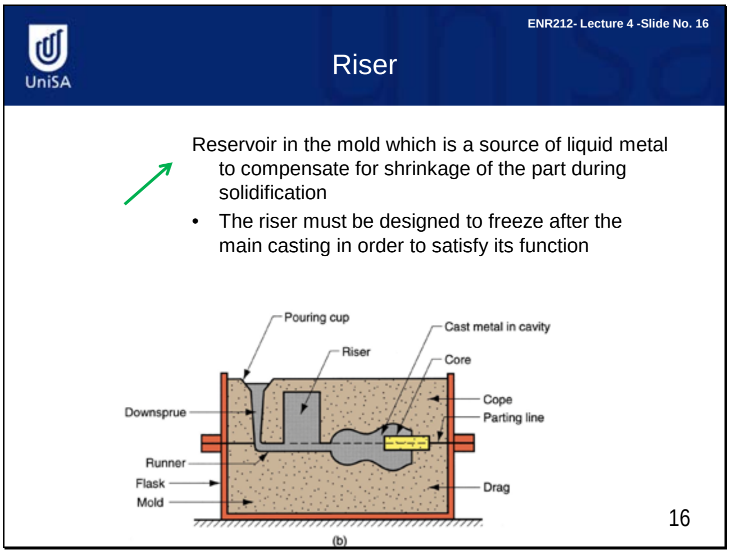

Now, as we have discussed, shrinkage can be a serious problem. Any casting in which shrinkage is significant requires a riser connected to the main cavity, in addition to the gating system. The riser is a reservoir in the mould that serves as a source of liquid metal for the casting, to compensate for shrinkage during solidification. Here are three questions to research for interest:

One. Is a riser a metal piece that is not a part of the casting?

Two. Is a riser a source of molten metal to feed the casting and compensate for shrinkage during solidification?

Three. Is a riser waste metal that is usually recycled?

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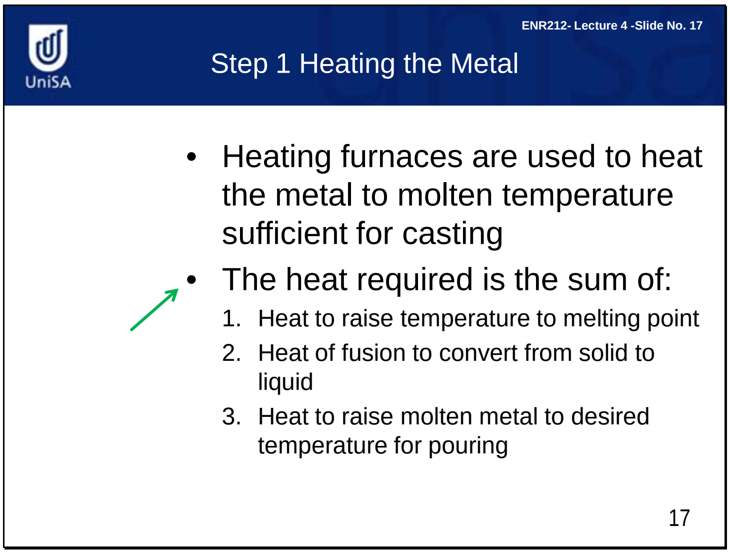

Heating furnaces of various kinds are used to heat the metal to a molten temperature sufficient for casting. The heat energy required is the sum of the following three energies: first, the heat to raise the temperature to the melting point, second, the heat of fusion to convert it from solid to liquid, and third, the heat to raise the molten metal to the desired temperature for pouring.

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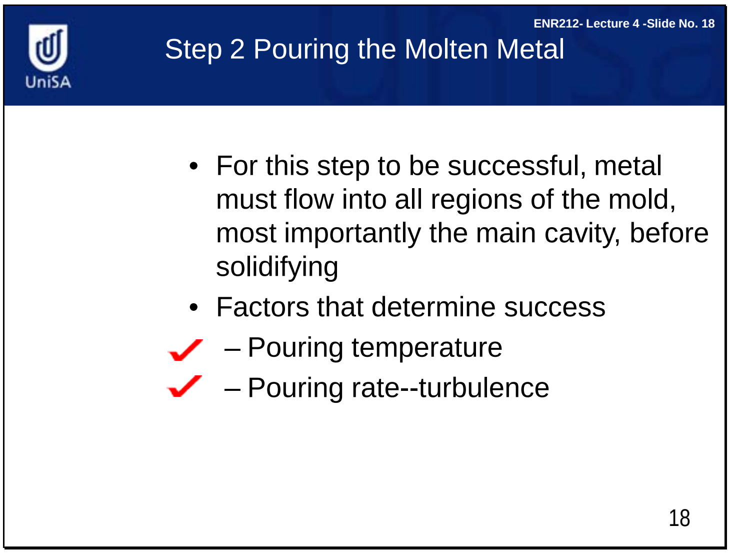

After heating, the metal is ready for pouring. The introduction of molten metal into the mould, including its flow through the gating system and into the cavity, is a critical step in the casting process. For this step to be successful, the metal must flow into all regions of the mould before solidifying. The factors which affect the pouring operation include the pouring temperature, the pouring rate, and the turbulence.

The pouring temperature is the temperature of the molten metal as it is introduced into the mould. There is a difference between the temperature at pouring and the temperature at which freezing begins.

The pouring rate refers to the volumetric rate at which the molten metal is poured into the mould. If the rate is too slow, the metal will chill and freeze before filling the cavity. If the pouring rate is excessive, turbulence can become a serious problem.

The turbulence in the fluid flow is characterized by erratic variation in the magnitude and direction of the velocity throughout the fluid. Turbulence must be avoided because it increases the erosion of the mould surfaces, and it increases the formation of metallic oxides that can become entrapped during solidification.

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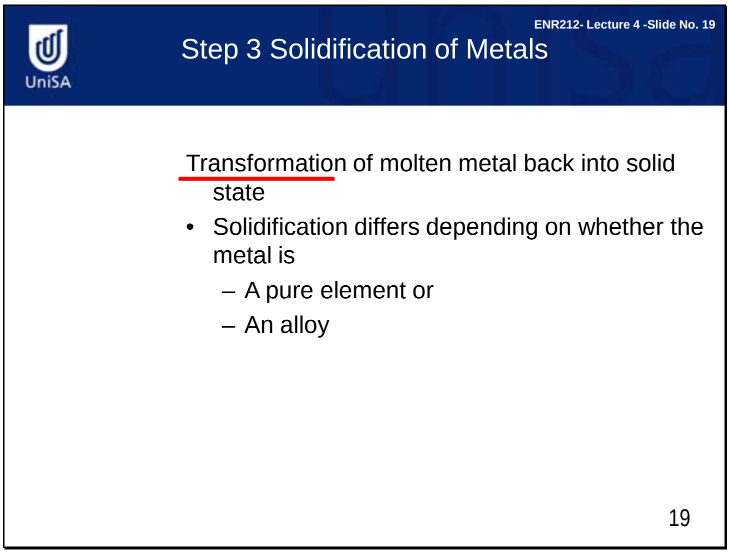

Solidification involves the transformation of the molten metal back into the solid state. The solidification process differs depending on whether the metal is a pure element or an alloy.

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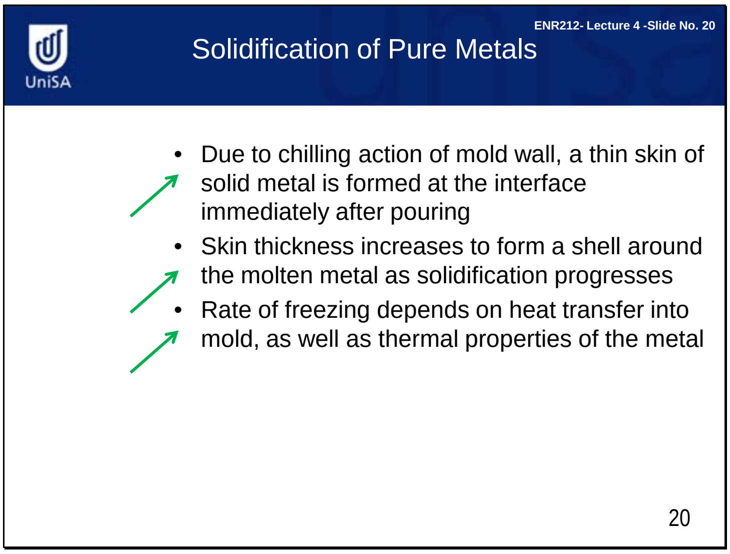

When molten metal is chilled, a thin skin of solid metal is initially formed at the interface immediately after pouring.
The thickness of the skin increases to form a shell around the molten metal as solidification progresses inward toward the centre of the cavity.
The rate at which freezing proceeds depends on heat transfer into the mould, as well as the thermal properties of the metal.

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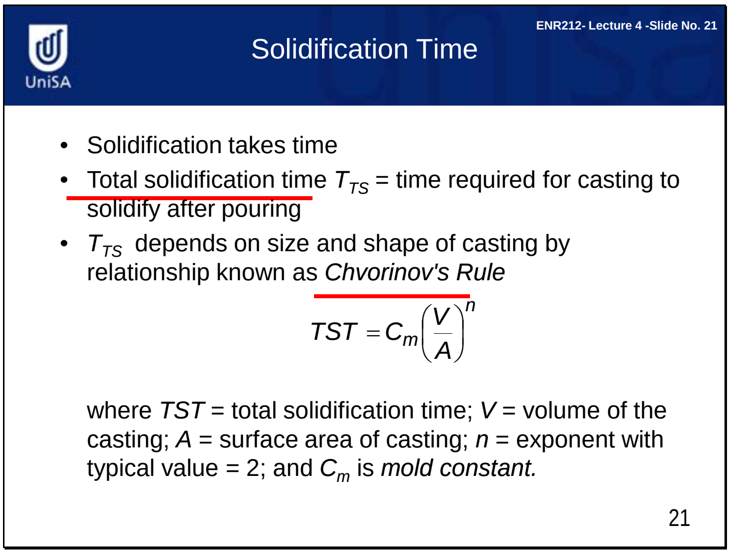

The total solidification time is the time required for the casting to solidify after pouring. This time is dependent on the size and shape of the casting by an empirical relationship known as Chvorinov's rule.

The mould constant C m depends on the particular conditions of the casting operations, including mould materials, thermal properties of the cast metal and pouring temperature.

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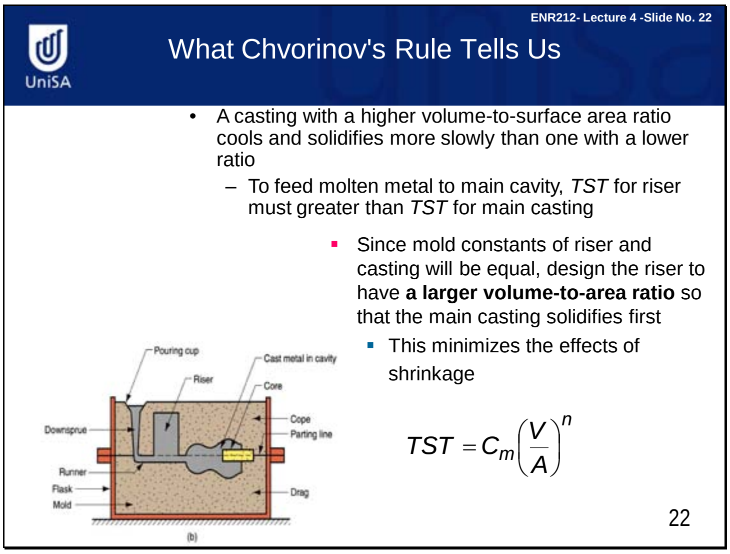

What does Chvorinov's Rule Tell Us ?
It tells us that a casting with a higher volume-to-surface area ratio cools and solidifies more slowly than one with a lower ratio.   So, using this rule, how do we design a riser? A riser should be designed to have a possibly larger volume-to-area ratio so that the main casting solidifies first.

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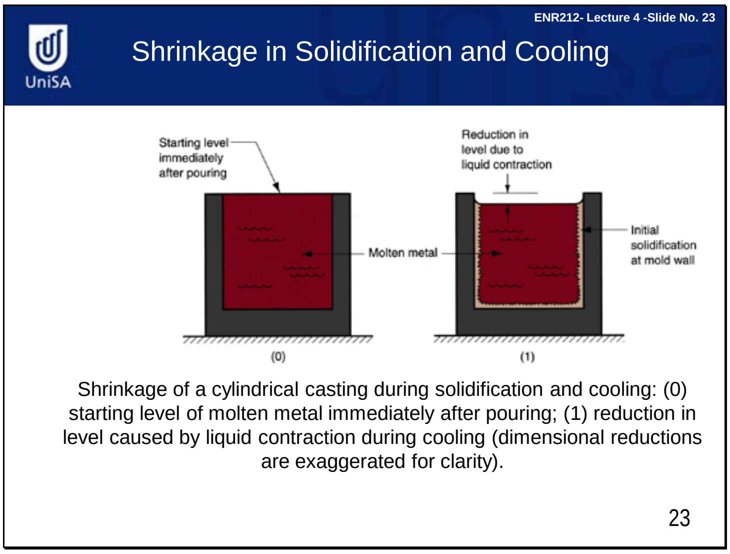

Shrinkage occurs in three steps:

First, when the liquid contracts during cooling, prior to solidification.
Second, the solid contracts during the phase change from liquid to solid.
Third, in thermal contraction of the solidified casting during cooling to room temperature.

Above here you can see the temperature-time plot for the three steps. These steps can be explained with reference to a cylindrical casting made in an open mould, as you can see on this slide and the next. Figure 0 shows the molten metal immediately after pouring. Liquid contraction occurs from figure 0 to figure 1, and this causes the height of the liquid to be reduced from its starting level, as you can see in figure 1. A thin metal wall is formed between the mould and the molten metal.

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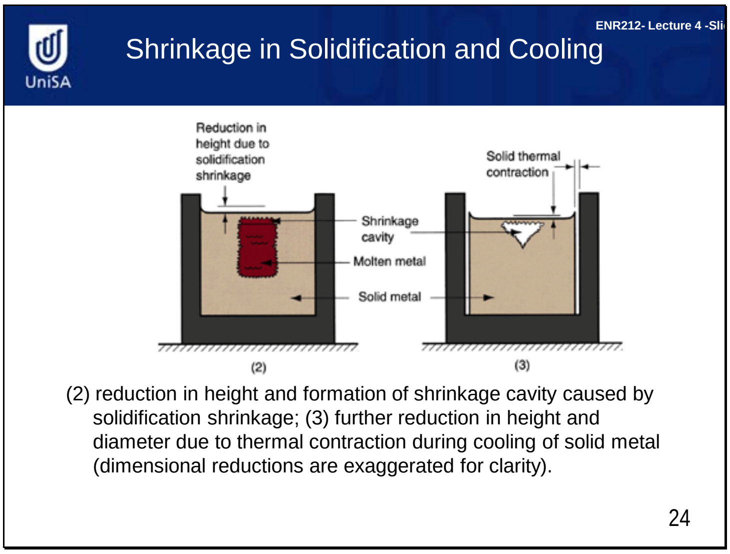

Solidification contraction occurs from figure 1 to figure 2. Because the molten metal solidifies inward towards the top centre, with obvious shrinkage, metal flows from the top centre towards the surround region. Therefore, there is always a void in the final region to freeze, as shown in Figure 3. This void is created by the absence of metal, and is called a pipe. Once solidified, the casting experiences further contraction in height and diameter.

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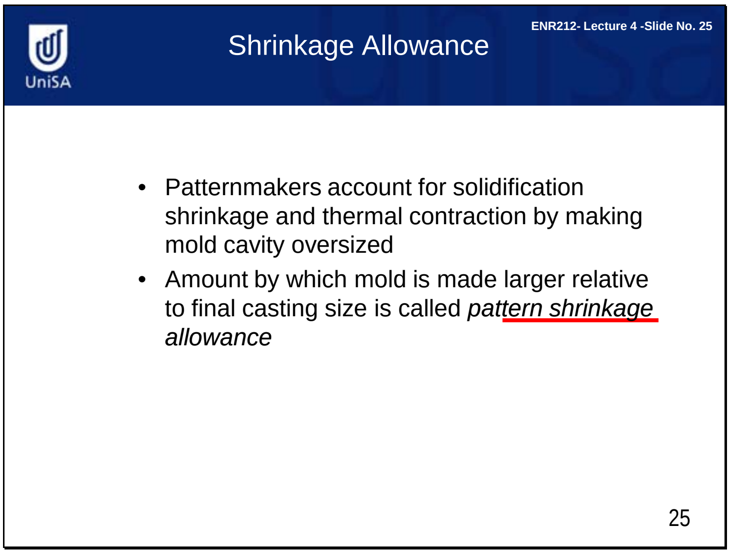

Pattern-makers account for solidification shrinkage and thermal contraction by making the mould cavities oversized. The amount by which the mould must be made larger relative to the final casting size is called the pattern shrinkage allowance.

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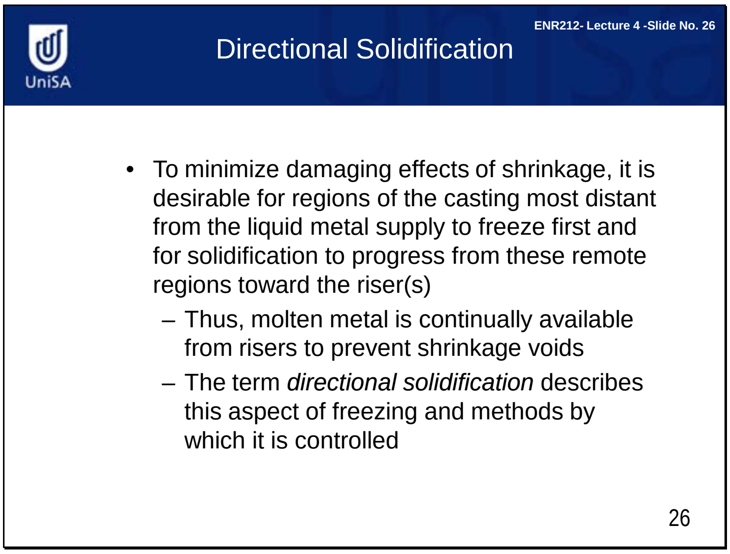

In simple words, directional solidification is a metal solidification in which the molten metal is controlled to solidify from the remote regions toward the risers.

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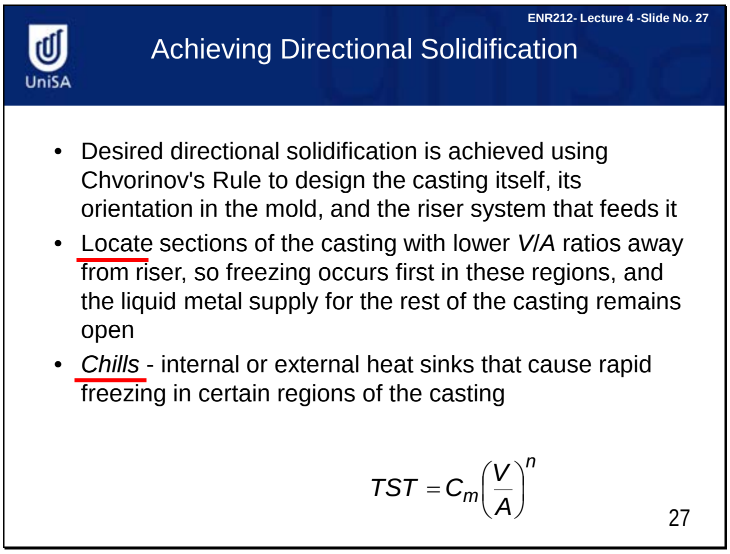

Chvorinov's rule can be used to achieve direction solidification by mould design. For example, we can locate parts of the casting with lower ratios away from the riser, so solidification occurs first in these regions, and there is still molten metal supply for the rest of the parts. We use chills to achieve rapid freezing.

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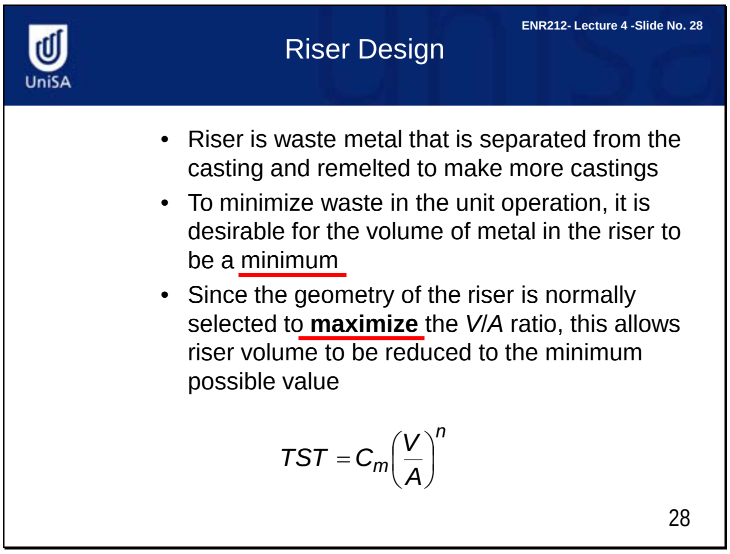

The riser is waste metal that is separated from the casting and remelted to make more castings. To minimize waste in the unit operation, it is desirable for there to be a minimum volume of metal in the riser. Since the geometry of the riser is normally selected to maximize the V over A ratio, this allows riser volume to be reduced to the minimum possible value.

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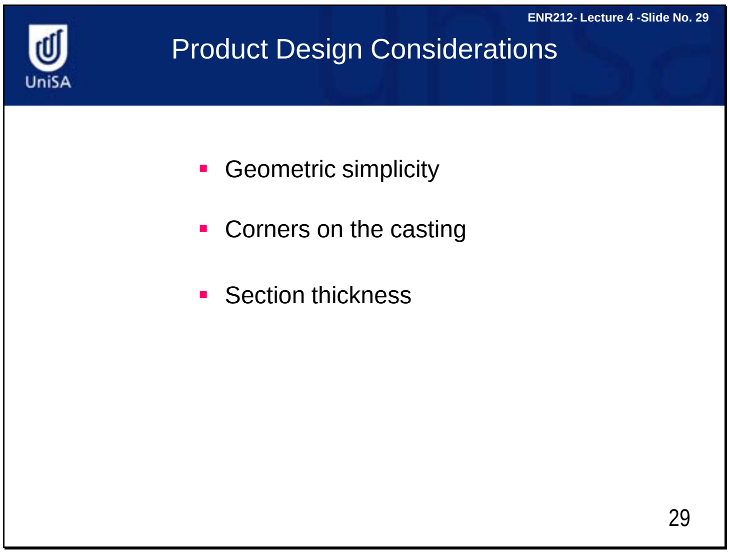

Although casting can be used to produce complex part geometries, simplifying the part design usually improves castability. Sharp corners and angles should be avoided, since they are sources of stress concentrations and may cause hot tearing and cracks. Section thicknesses should be uniform in order to avoid shrinkage cavities.

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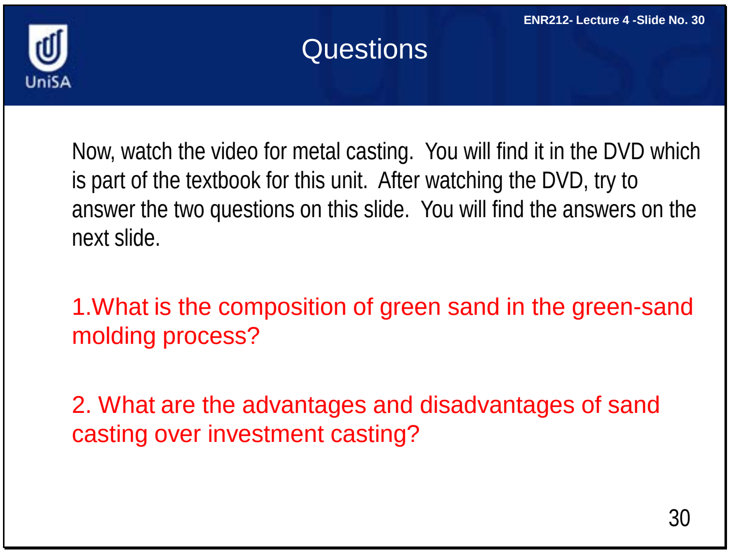
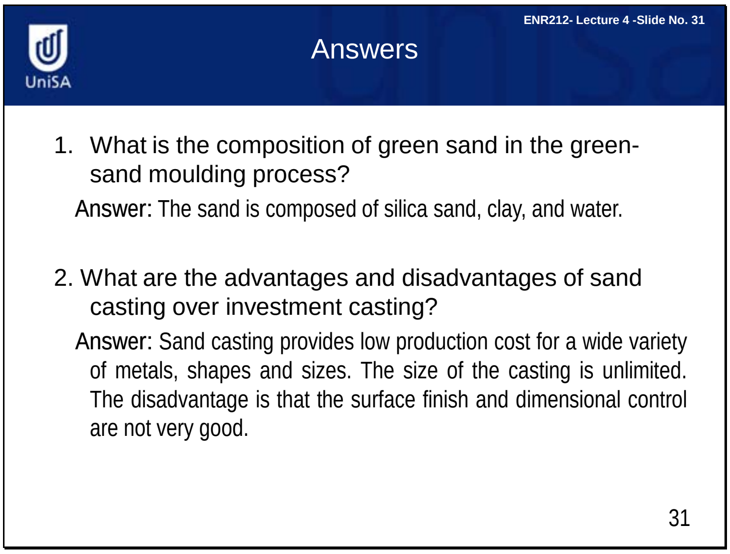


Now, watch the video for metal casting. You will find it in the DVD which is part of the textbook for this unit. After watching the DVD, try to answer the two questions on this slide. You will find the answers on the last slide of the presentation. Thank you for your attention.

Slide 31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Answers
1. What is the composition of green sand in the green-sand moulding process?
Answer: The sand is composed of silica sand, clay, and water.
2. What are the advantages and disadvantages of sand casting over investment casting?
Answer: Sand casting provides low production cost for a wide variety of metals, shapes and sizes. The size of the casting is unlimited. The disadvantage is that the surface finish and dimensional control are not very good.
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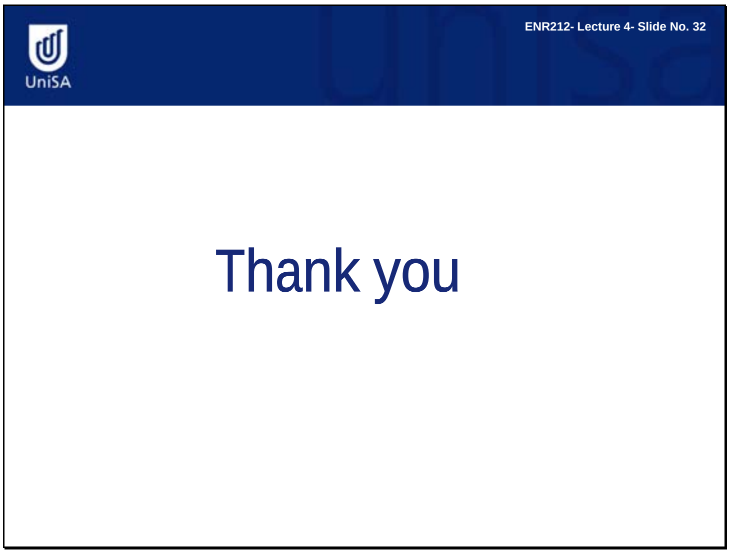

Thank you for your attention.