Ice-cream Making:
Primitive ice cream contained no milk (fruit flavors were frozen).

Types:
Frozen custards: also known as French ice cream (includes eggs).
Sorbet: no added dairy, just fruits and sugars, lightest.
Sherbet: sorbet + cream, milk, egg whites, gelatin (sometimes with buttermilk), lighter than ice cream.
Gelato: Italian ice cream, made of milk, cream, and sugar, contains less air, more flavor, lower fat and higher sugar levels.
Frozen Yogurt

The market:
Total ice cream sales in the US amount to $20 billion, most of which occur outside the household. California is the largest state in terms of ice cream production (175m gallons).
Major Ice cream manufacturers include Nestle (18% of the worldwide production), Unilever and McDonalds.
Trends in ice cream are not just temperature specific, they are culture-oriented as well: Eastern Asia doesn't have a significant amount of consumption but has a significant population size.

Categorizing and segmenting ice cream production:
Portioned ice cream (separately produced portions such as sticks and bars) vs. **Non-Portioned Ice cream** (non-portioned, continuously produced amounts, portioned after production)
Out of home (2/3) vs at Home (1/3)
Most **portioned ice cream** (22% out of 33%) is consumed "**impulsively**" and can be sold by several local and whole-sale parties.
Most non-portioned ice cream (44% out of 67%) is consumed outdoors (in the form of scooping or slush) and is sold in shops.
At home-consumption which constitutes 34% of the total consumed ice cream is consumed as "multipacks" (11% out of 34%) or as desserts (very popular in the US and some of Europe, sold in family-sized portions), both are purchased at grocery stores.
The "impulsive" market is important for "hot" countries

Ice cream Composition:
1- **Milkfat:** Anything below 10% is not full fat ice cream, "premium" ice cream can contain up to 16%
2- **Milk Macromolecules:** 9-12% of the other milk solids including Lactose, Protein and minerals
3- **Sweetners and Sugar**: 12-16% of sugar is a huge number (regular sugar or syrup) yet the ice cream doesn't usually taste as sweet as colas due to the other components present in it
4- **Stabilizers and emulsifiers: 0.5-0.5%**
   Stabilizers: prevent the growth of ice crystals by forming a matrix/mesh for holding the crystals and components of the ice cream and preventing crystal growth
   emulsifiers are to spread and decrease fat globule size
5- 2/3 is **water,** 90% of which is converted to ice
6- **Air** is present in ice cream in huge amounts [20% - 100%]

Overrun: calculating the air that should be present (50% by air volume for 100% overrun):
For a 200ml Ice cream mix (thick liquid), take the sample's weight=200g and fill the same volume with its weight as air

$$Overrun = \frac{Weight\ of\ Mix - Weight\ of\ Icecream}{Weight\ of\ Icecream} \times 100$$

When overrun= 100%, air volume constitutes 50% of the ice cream with the other 50% being the ice cream
The less the overrun is, the better the quality, the higher the density of the ice cream.

Structure:
It's a foam, a gel, an emulsification, ice crystals [20<35<60] as the size limit for the size which is indirectly proportional to quality measures, and air cells [5<60<300] microns in size

Proteins, minerals, and sugar (are the solid matrix in the background)

Home vs. Industrial Ice cream:
The longer the freezing time while preparing ice cream (like at home) the larger is the expected crystallization.
Less overrun, is another issue with homemade ice cream due to mixing methods meaning that the prepared ice-cream cannot be stored for long periods

Phases of Production: system may be continuous (for batch making in mass production): **exit temperature -5^{o}C, refrigerant temperature -30^{o}C**

1- **Mixing at 45-65degC**
possible liquid components are cream water syrup emulsifiers flavors, possible solid components are milk powder (as a potential replacement to liquid milk) and other solids.
Ingredients added at proper temperatures and sequence and are agitated with heat
Turbine propeller (fan) quickly and adequately mixes the batter (adding of the mix must be done gradually)
2- **Homogenization at 55^{o}C** reduces fat globule size by 2 microns, in two steps:
first stage homogenization: at pressure **2000psi to 500psi** the product's globules are broken down
second stage homogenization: narrower opening **with increasing pressure to 2000psi** breaks the clusters of previously broken globules
Homogenization, improves air stability, texture, and ensures less melting: hydrophobic components arrange to the inside of present air bubbles (the hydrophobic layer preserves the air bubble)
emulsifiers maintain the integrity of air cells (hydrophobic inside)
3- **Pasteurization at 83^{o}C at 13sec**. mixture subjected to higher temperature than milk due to the higher amounts of components in the ice cream
4- **Aging and flavoring**: the gum requires a lot of time so it's left at **4^{o}C for 2 hours for the matrix to form**
5- **Freezing and Air Incorporation**: in the freezer there's a stationary cylinder barrel container with rotating scraper (**mixing scraping and air incorporating due to openings and pressure) exit temperature must be -5^{o}C.**
6- Incorporated material in ice cream (**variegates) are added at -5^{o}C** which occurs once the ice cream released from the freezer, it's then conveyed under freezing conditions -18^{o}C through the ice cream tunnel during where it hardens and is then stored at -30^{o}C

Types of Freezers:
Ice cream freezing is two stages: Freezing and Hardening, both must be accompanied for.
Continuous ice cream making systems (industrial): Freezing, air incorporation, fat globule aggregation
Semi-continuous soft serve freezer (for service)
Batch freezer (batch products made in the industry or at home): "batch in batch out"

-freezing in a scrapped surface heat exchanger: high rate of heat-transfer due to friction produced, high nucleation rate (crystal nuclei formation)
-the goal of freezing is to produce the largest number of smaller-size ice crystals at a given temperature)
-in the hardening phase, the goal is to minimize recrystallization and coalescence of air cells. This can be achieved by fast cooling.
-hardening in a **forced air cooler**, heat transfer is limited (conduction through the product itself)
-no new crystals are formed.
-Foam on the outside of the cylinder prevents any loss of energy
The rotating dasher is very important; it's porous and creates liquid-air foam in the ice cream

Crystallization control:
Goals: Achieving the smallest possible crystal sizes in the first phase and to achieve minimal crystal-growth-rate along the hardening phase. The two goals can be achieved by having the freezer exit temperature to as low as possible.
Rotation of blades: speed: **very fast rotation and very sharp blades** are adequate for scraping and for attaining tiny ice crystals (keep in mind that mechanical energy accounts for 50% of the total produced heat in the process which affects the production)
Fluid Flow Force breaks large air bubbles into smaller ones (depends on the dasher rotation speed, residence time, gas-liquid ratio, and the viscosity of the mixture in its liquid phase

The ice cream freezer produces the greatest quality ice cream
Surface area/Mass: the smaller the surface area, the higher is the ratio producing smaller ice crystals
Recrystallization: **Ostwald Ripening** (large ice crystal formation with time)
Aggregation: fusion of two small ice crystals into a larger one due to fluctuation of temperature or due too much water and too little gum, or if not stored at -30^{o}C

The freezing Heat process in the tubular heat exchanger:
Ice cream mix is 66% water
In the freezer, [29-40%], **35%** (1/2 of the water content) is frozen
(The higher ice content, less growth in the hardening tunnel, the lower it is **29%, more growth will occur**

Exit temperature: the exit phase needs to be a semi solid: as low as possible

The lower the exit temperature the better the growth of crystals after exit and for the incorporation of more air
The longer the mix remains the larger crystals grow and with more quantity
Short residence time: flow rate/dasher (better for ice, bad for air)
Moderate dasher rotation speed (faster better for air

During the hardening phase (in the hardening tunnel): 55% (80% of the water) is frozen: the existing ice crystals now grow in size (the size limits the ice cream quality) during the hardening phase it's important for the ice crystals not to be large.
Heat: heat from the rotating dasher is due to its rotation speed; almost 50% of the heat created is due to mechanical energy.

Melting behavior of ice cream, dripping quantity collected when a know amount of ice cream melts.

Ice cream defects:
Lactose precipitation (sandy texture): irreversible, due to temp fluctuations
Higher altitudes and decrease in at pressure induces pressure on the extra layer of outer chocolate; a way to solve this is by **decreasing overrun**: an increase in the size of the air bubbles wont be so drastic as to crack the outer chocolate layer.