Cell culture BASICS

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Further Reading on Cell Culture Techiques

- Cell Biology, A Laboratory Handbook
- Edited by Julio E. Celis
- Second Edition, Volume 1 – 4
- Academic Press

Extra resources

Qiagen
https://www.qiagen.com/za/resources/molecular-biology-methods/animal-cell-culture/

Gibco cell culture basics- material, videos and virtual culturing
http://www.thermofisher.com/za/en/home/references/gibco-cell-culture-basics.html

Amazing, thank you Gibco, not only am I learning a lot before I start my Quantitive Biology course in March, even better, it is an amazing way to get young biologists, if not already familiar with lab protocols, to learn protocols before they enter a lab.

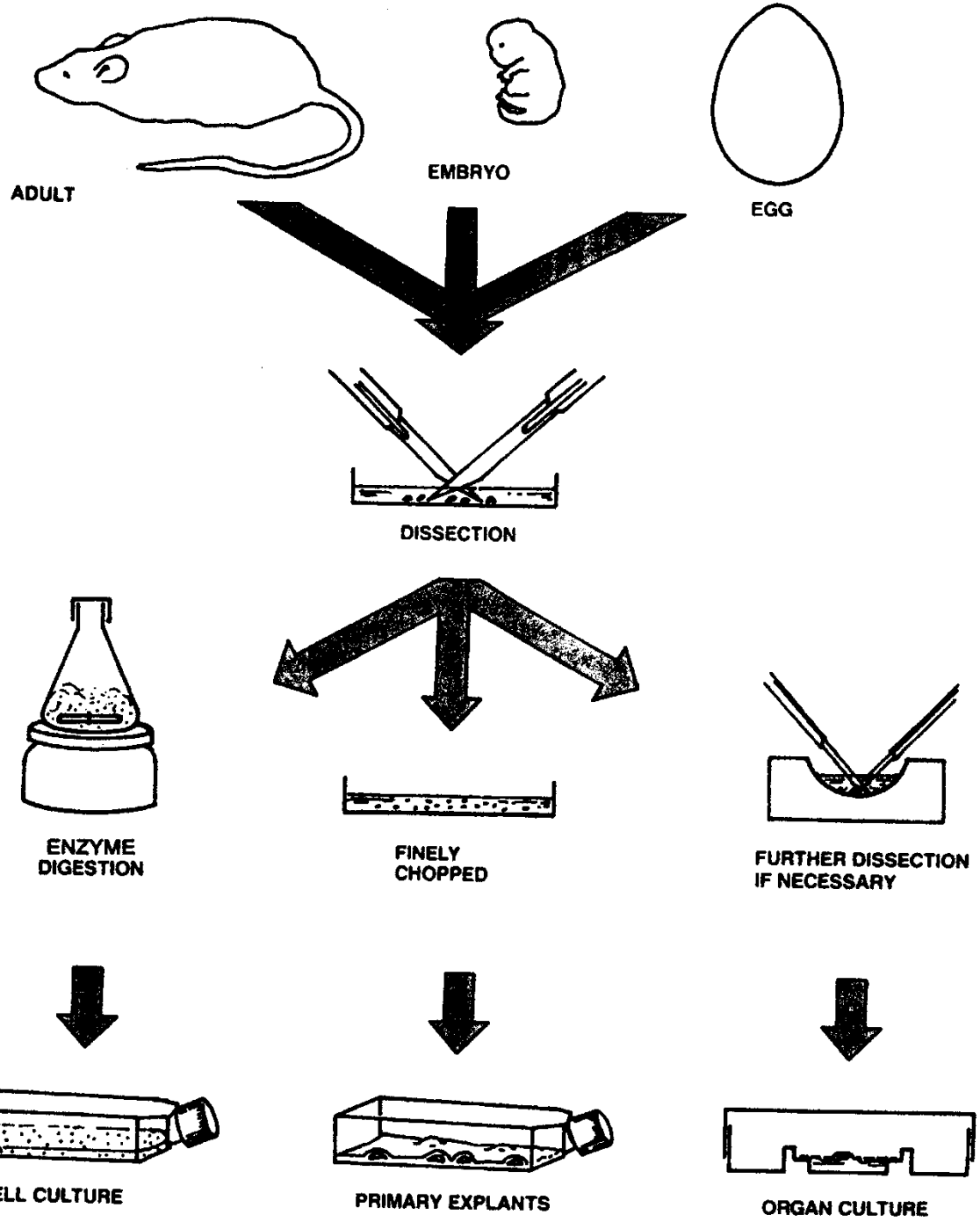
Gibco cell culture basics book
http://www.thermofisher.com/content/dam/LifeTech/global/life-sciences/pdfs/March2015_PG1315-PJ5831-CO012890-REPRINT-Gibco-Cell-Culture-Basics-Handbook-Americas-FLR.pdf

Learning Objectives

- After the session, students should be able to explain
  - the meaning of tissue culture and various types of cell cultures
  - the application of cell culture
  - the advantages and disadvantages of each type of cell culture
  - the significance of culture environment on cell culture
  - the basic procedure of cell culture
  - the safety considerations for cell culture work
  - Instrumentation and technologies used with cell culturing

What is tissue culture?

- In vitro culture (maintain and/or proliferate) of cells, tissues or organs
- Types of tissue culture
  - Organ culture
  - Tissue culture
  - Cell culture


ADULT
EMBRYO
EGG
DISSECTION
ENZYME DIGESTION
FINELY CHOPPED
FURTHER DISSECTION IF NECESSARY
CELL CULTURE
PRIMARY EXPLANTS
ORGAN CULTURE

Organ culture

- The entire embryos or organs are excised from the body and culture
- Advantages
  - Normal physiological functions are maintained.
  - Cells remain fully differentiated.
- Disadvantages
  - Scale-up is not recommended.
  - Growth is slow.
  - Fresh explantation is required for every experiment.

Tissue Culture

- Fragments of excised tissue are grown in culture media
- Advantages
  - Some normal functions may be maintained.
  - Better than organ culture for scale-up but not ideal.
- Disadvantages
  - Original organization of tissue is lost.

Cell Culture

- Tissue from an explant is dispersed, mostly enzymatically, into a cell suspension which may then be cultured as a monolayer or suspension culture.
- Advantages
  - Development of a cell line over several generations
  - Scale-up is possible
- Disadvantages
  - Cells may lose some differentiated characteristics.

What is cell culture used for?

Areas where cell culture technology is currently playing a major role.

- Model systems for

  Studying basic cell biology, interactions between disease causing agents and cells, effects of drugs on cells, process and triggering of aging & nutritional studies

- Toxicity testing

  Study the effects of new drugs

- Cancer research

  Study the function of various chemicals, virus & radiation to convert normal cultured cells to cancerous cells

Contd….

- Genetic Engineering

  Production of commercial proteins, large scale production of viruses for use in vaccine production e.g. polio, rabies, chicken pox, hepatitis B & measles

- Gene therapy

  Cells having a functional gene can be replaced to cells which are having non-functional gene

Advantages of Cell culture

- Advantages:
  - Absolute control of physical environment
  - Homogeneity of sample
  - Less compound needed than in animal models
- Disadvantages:
  - Hard to maintain
  - high cost
  - Dedifferentiation (loss of specialized function)
  - Instability, aneuploidy

Introduction

- Cell culture is the process by which prokaryotic, eukaryotic or plant cells are grown under controlled conditions. But in practice it refers to the culturing of cells derived from animal cells.
- Cell culture was first successfully undertaken by Ross Harrison in 1907
- Roux in 1885 for the first time maintained embryonic chick cells in a cell culture

Cell Culture *in vitro* - A brief history

- **1885: Roux maintained embryonic chick cells alive in saline solution for short lengths of time**
- **1912: Alexis Carrel cultured connective tissue and showed heart muscle tissue contractility over 2-3 months**
- **1943: Earle et al. produced continuous rat cell line**
- **1962: Buonassisi *et al*. Published methods for maintaining differentiated cells (of tumour origin)**
- **1970s: Gordon Sato et al. published the specific growth factor and media requirements for many cell types**
- **1979: Bottenstein and Sato defined a serum-free medium for neural cells**
- **1980 to date: Tissue culture becomes less of an experimental research field, and more of a widely accepted research tool**

Isolation of cell lines for *in vitro* culture

Resected Tissue

↓

Cell or tissue culture *in vitro*

↓

Primary culture

↓ Sub-culture

Secondary culture

↓ Sub-culture

Cell Line

↓

Immortalization

↓ Loss of control of cell growth

Transformed cell line

Immortalised cell line

mutations

Finite culture

Continuous culture

Good Read:
https://www.lonza.com/products-services/bio-research/primary-cells/primary-cells-vs-cell-lines.aspx

https://www.biocat.com/cell-biology/cell-immortalization

1- Growth factor independency
2- No response to growth inhibitors
3- Evasion of apoptosis
4- Can promote angiogenesis
5- Unlimited proliferation
6- Invasive

Types of cell cultures *in vitro*

Primary cultures

- **Derived directly from animal tissue**
  embryo or adult? Normal or neoplastic?
- **Cultured either as tissue explants or single cells**
- **Finite life span *in vitro***
- **Retain differentiated phenotype**
- **Mainly anchorage dependant**
- **Exhibit contact inhibition**

Contact inhibition is a growth mechanism which functions to keep cells growing into a layer one cell thick (a monolayer)

Types of cell cultures *in vitro*

Secondary cultures

- **Derived from a primary cell culture**
- **Isolated by selection or cloning**
- **Becoming a more homogeneous cell population**
- **Finite life span *in vitro***
- **Retain differentiated phenotype**
- **Mainly anchorage dependant**
- **Exhibit contact inhibition**

Continuous cell lines

- Infinite life span
- Authenticated cell lines (no contamination, defined morphology, lineage)
- ATCC (American Type Culture Collection) or ECACC (European Collection of Authenticated Cell Cultures)

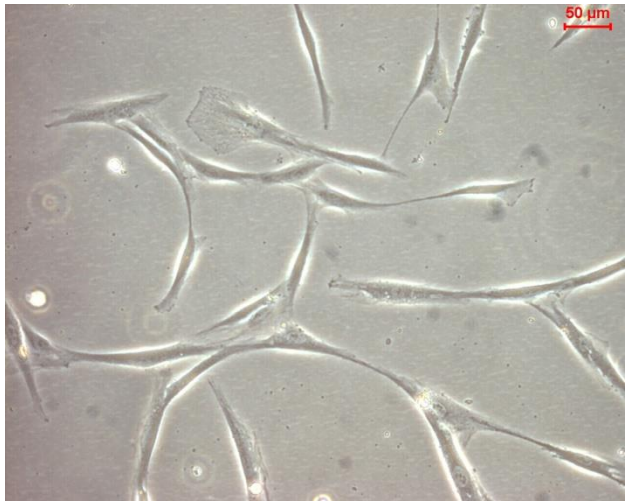
Types of cells

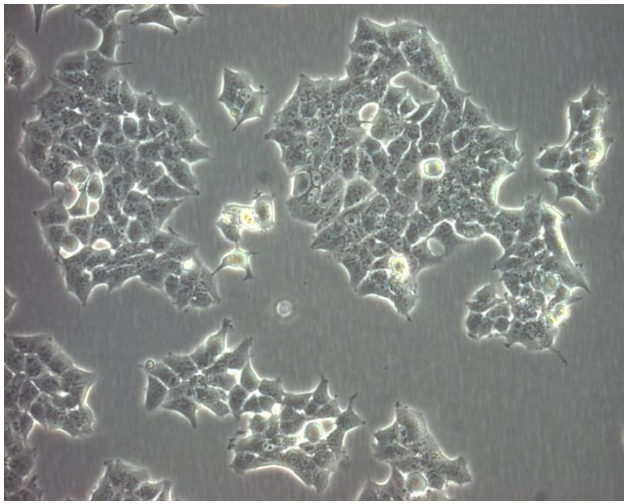
On the basis of morphology (shape & appearance) or on their functional characteristics. They are divided into three.

- **Epithelial** like-attached to a substrate and appears flattened and polygonal in shape
- **Lymphoblast** like- cells do not attach, remain in suspension with a spherical shape
- **Fibroblast** like- cells attached to an substrate appears elongated and bipolar

Cell morphologies vary depending on cell type

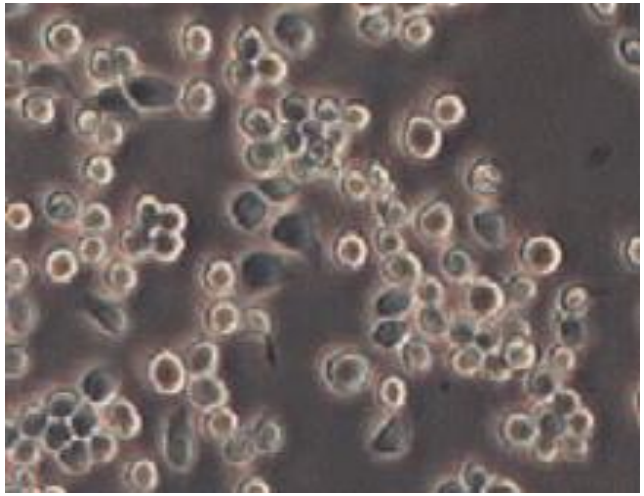
Fibroblastic





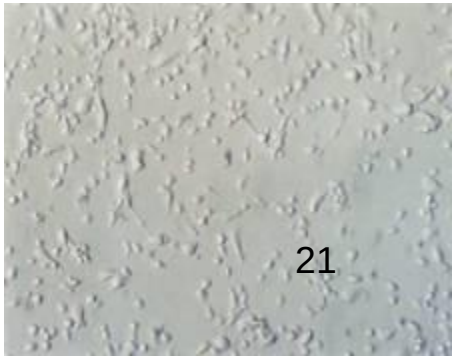
Epithelial

Lymphoblastic



Culturing of cells

- Cells are cultured as anchorage dependent or independent
- Cell lines derived from tissues are considered as anchorage-dependent grows only on a suitable substrate e.g. tissue cells
- Suspension cells are anchorage-independent e.g. blood cells
- Transformed cell lines either grow as monolayer or as suspension



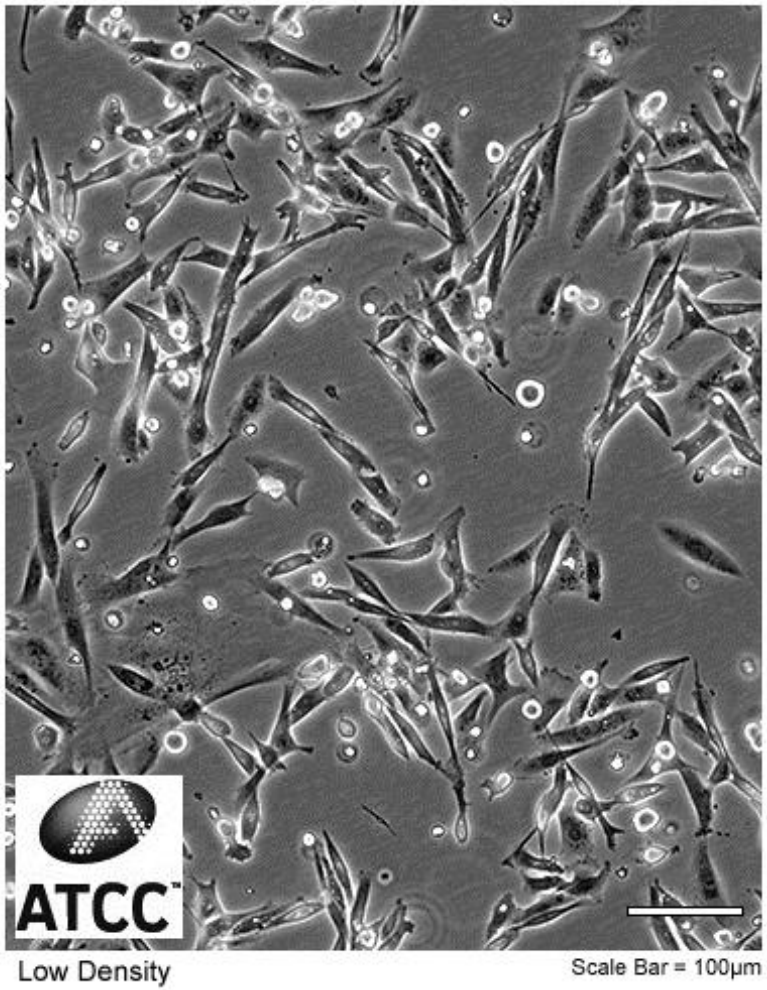
Major developments in cell culture technology

- First development was the use of antibiotics which inhibits the growth of contaminants.
- Second was the use of trypsin to remove adherent cells to subculture further from the culture vessel
- Third was the use of chemically defined culture medium.

Adherent cells

- Cells which are anchorage dependent
- Cells are washed with PBS (free of ca & mg) solution.
- Add enough trypsin/EDTA to cover the monolayer
- Incubate the plate at 37 ˚C for few minutes
- Add complete medium to dissociate and dislodge the cells and inactivate trypsin, mix with pipette
- Add complete medium depends on the subculture
- Requirement either - 25 cm or 75 cm flask

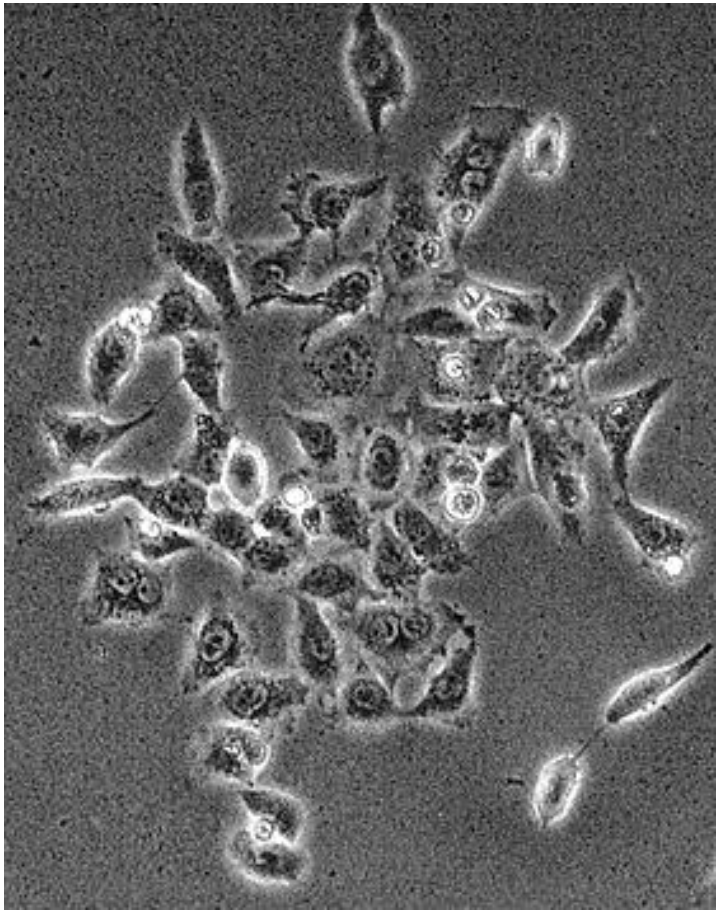
MDA-MB-231 (Human breast adenocarcinoma)



- Elongated with spindle-like projections
- Metastatic (derived from breast tissue)
- Isolated from pleural effusion (metastasised to lung tissue)

Adapted from: http://www.atcc.org/products/all/HTB-26.aspx

HEK (Human embryonic kidney cells)



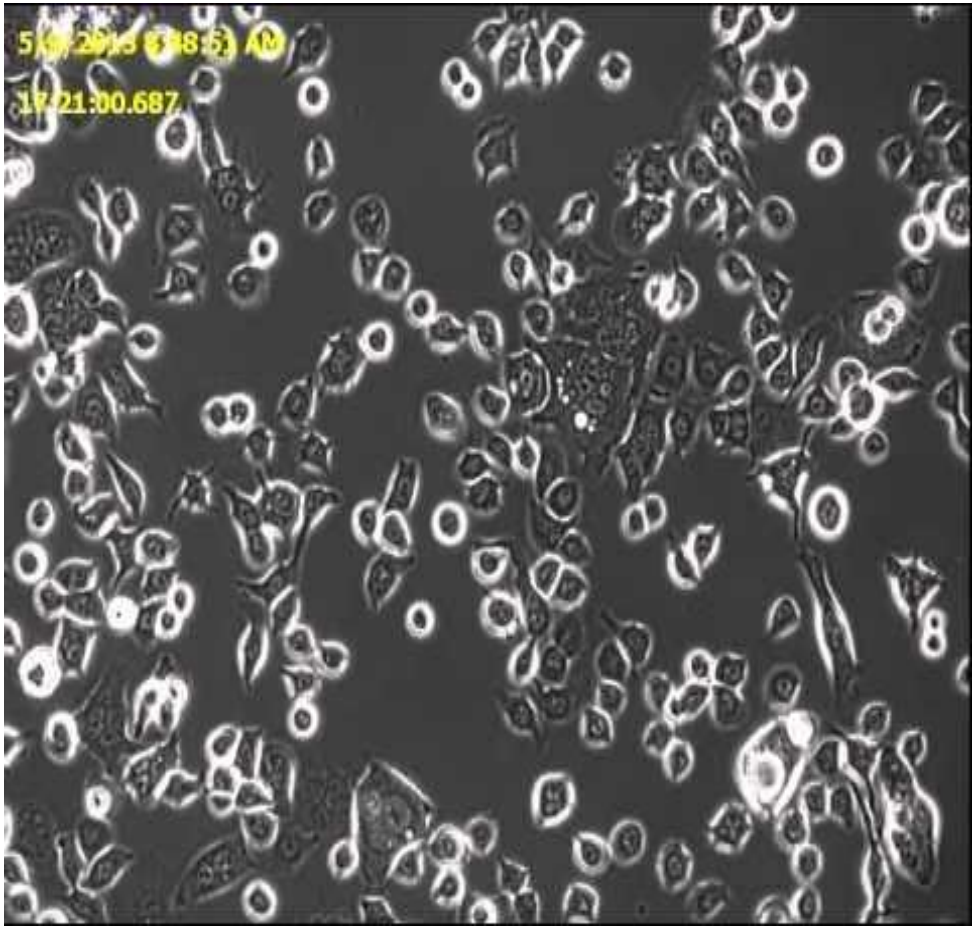
http://en.wikipedia.org/wiki/HEK_293_cells

- Rounded in shape with spindle-like edges
- Derived from human embryonic kidney cells grown in tissue culture
- Epithelial-like morphology

Suspension cells

- Easier to passage as no need to detach them
- As the suspension cells reach to confluency
- Asceptically remove 1/3rd of medium
- Replaced with the same amount of pre-warmed medium

AsPC-1 pancreatic cancer cells



- Spherical with spindle-like protrusions/ endings
- Rapid and aggressive growth
- Metastatic
- Derived from the ascites of a patient with pancreatic cancer

https://www.google.com/search?q=aspc+1+cells&source=lnms&tbm=isch&sa=X&ei=WEn4VKHpNsavU-yhhNgO&ved=0CAcQ_AUoAQ&biw=1240&bih=890#imgdii=_&imgrc=bdFPKhnW-jbAGM%253A%3BwL6rCSSpvQDzHM%3Bhttp%253A%252F%252Fi1.ytimg.com%252Fvi%252F4GNactizyhg%252F0.jpg%3Bhttp%253A%252F%252Farticle.wn.com%252Fview%252F2014%252F04%252F29%252FChina_acts_on_dumping_of_TBHQ_imports%252F%3B480%3B360

How do we culture cells in the laboratory?

Revive frozen cell population
Isolate from tissue

⇩

Maintain in culture (aseptic technique)

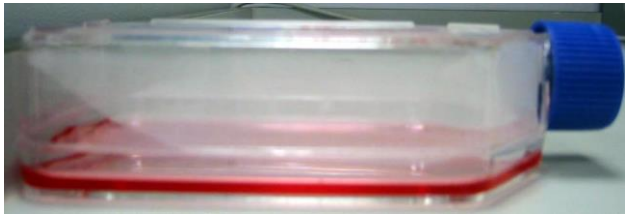
⇩

Sub-culture (passaging)

⇩ **Count cells**

Cryopreservation

Containment level 2 cell culture laboratory



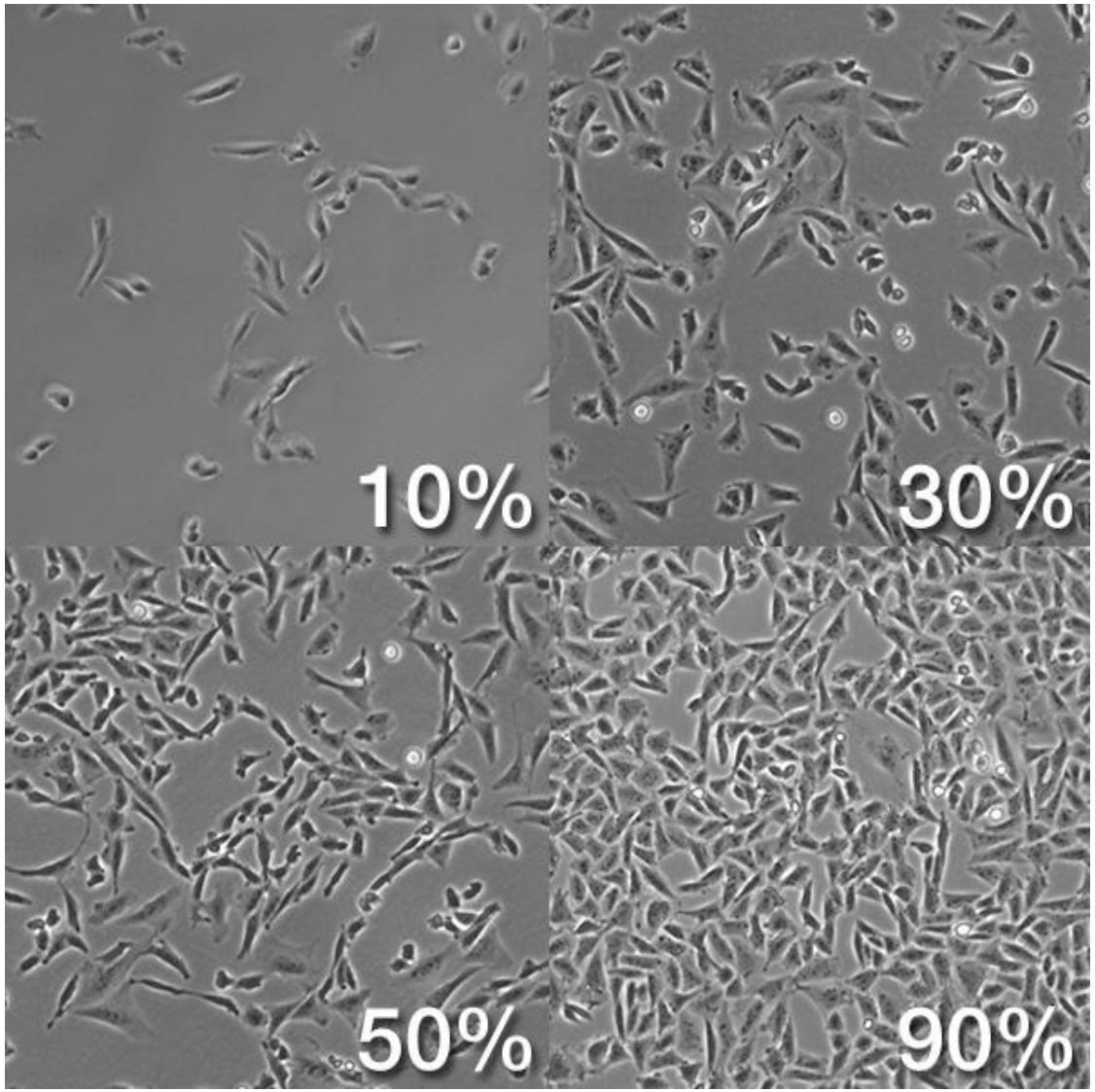
Typical cell culture flask

‘Mr Frosty’
Used to freeze cells

Why sub-culturing?

- Once the available substrate surface is covered by cells (a confluent culture) growth slows & ceases.
- Cells to be kept in healthy & in growing state have to be sub-cultured or passaged.
- It's the passage of cells when they reach to 80-90% confluency in flask/dishes/plates

Confluency



Passaging Cells

Check confluency of cells

⇩

Remove spent medium

⇩

Wash with PBS

⇩

Incubate with trypsin/EDTA

⇩

Resuspend in serum containing media

⇩

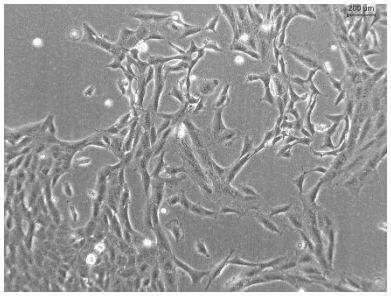
Transfer to culture flask

Why passage cells?

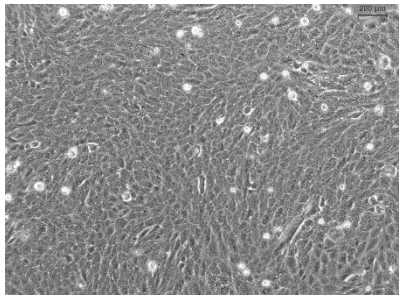
- To maintain cells in culture (i.e. don't overgrow)
- To increase cell number for experiments/storage

How?

- 80% confluency
- Wash in PBS to remove dead cells and serum
- Trypsin digests protein-surface interaction to release cells
- EDTA enhances trypsin activity
- Resuspend in media (inactivates trypsin)
- Transfer dilute cell suspension to new flask (fresh media)
- Most cell lines will adhere in approx. 3-4 hours

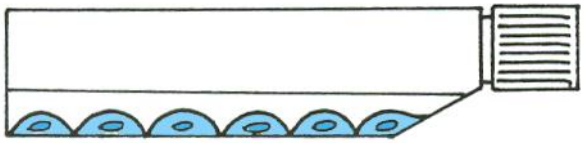


70-80% confluence



100% confluence

The cell culture environment



Factors affecting cell behaviour *in vivo*

- The local micro-environment
- Cell-cell interactions
- Tissue architecture
- Tissue metabolites
- Locally released growth factor and hormones

Cell culture environment (*in vitro*)

What do cells need to grow?

- **Substrate or liquid (cell culture flask or scaffold material)**
  - **chemically modified plastic or coated with ECM proteins**
  - **suspension culture**
- **Nutrients (culture media)**
- **Environment (CO_2, temperature 37^{o}C, humidity)**
  - **Oxygen tension maintained at atmospheric but can be varied**
- **Sterility (aseptic technique, antibiotics and antimycotics)**
  - **Mycoplasma tested**

Cell culture environment (*in vitro*)

Basal Media

- Maintain pH and osmolarity (260-320 Osm/L).
- Provide nutrients and energy source.

Components of Basal Media

Inorganic Salts

- Maintain osmolarity (solute conc.)
- Regulate membrane potential (Na^+, K^+, Ca^{2+})
- Ions for cell attachment and enzyme cofactors

pH Indicator – Phenol Red

- Optimum cell growth approx. pH 7.4

Buffers (Bicarbonate and HEPES)

- Bicarbonate buffered media requires CO_2 atmosphere
- HEPES Strong chemical buffer range pH 7.2 – 7.6 (does not require CO_2)

Glucose

- Energy Source

HEPES: 4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid

Cell culture environment (*in vitro*)

Components of Basal Media

Keto acids (oxalacetate and pyruvate)

- Intermediate in Glycolysis/Krebs cycle
- Keto acids added to the media as additional energy source
- Maintain maximum cell metabolism

Carbohydrates

- Energy source
- Glucose and galactose
- Low (1 g/L) and high (4.5 g/L) concentrations of sugars in basal media

Vitamins

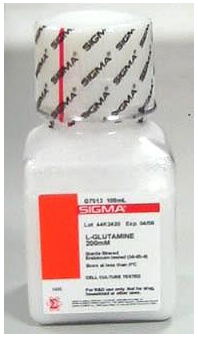
- Precursors for numerous co-factors
- B group vitamins necessary for cell growth and proliferation
- Common vitamins found in basal media is riboflavin, thiamine and biotin

Trace Elements

- Zinc, copper, selenium and tricarboxylic acid intermediates

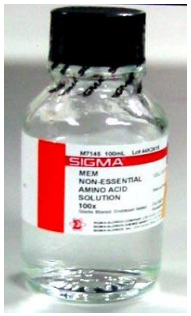
Cell culture environment (*in vitro*)

Supplements



L-glutamine

- Essential amino acid (not synthesised by the cell)
- Energy source (citric acid cycle), used in protein synthesis
- Unstable in liquid media - added as a supplement



Non-essential amino acids (NEAA)

- Usually added to basic media compositions
- Energy source, used in protein synthesis
- May reduce metabolic burden on cells

Growth Factors and Hormones (e.g.: insulin)

- Stimulate glucose transport and utilisation
- Uptake of amino acids
- Maintenance of differentiation

Antibiotics and Antimycotics

- Penicillin, streptomycin, gentamicin, amphotericin B
- Reduce the risk of bacterial and fungal contamination
- Cells can become antibiotic resistant – changing phenotype
- Preferably avoided in long term culture

pH Control

- Physiological pH 7
- pH can affect
  - Cell metabolism
  - Growth rate
  - Protein synthesis
  - Availability of nutrients
- CO_2 acts as a buffering agent in combination with sodium bicarbonate in the media

(-pKa of sodium bicarbonate is 6.3 at 37°C which results in suboptimal buffering throughout the physiological pH range.
-carbon dioxide is released in the atmosphere with a resulting increase in alkalinity)

Temperature and Humidity

- Normal body temperature 37^{o}C

- Humidity must be maintained at saturating levels as evaporation can lead to changes in
  - Osmolarity
  - Volume of media and additives

Introduction of Cell Culture Lab (Equipment)

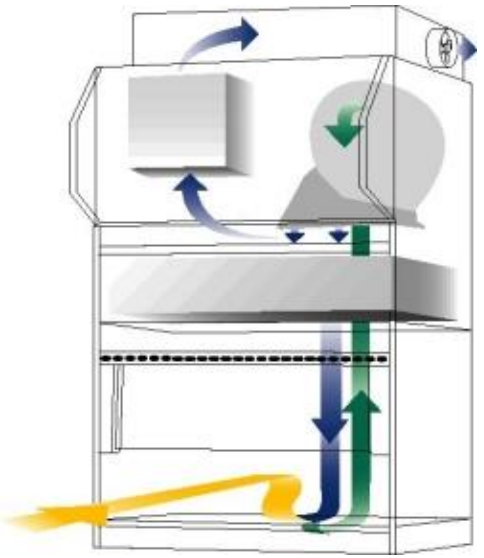
- CO_2-thermostats
- Airflow
- Solutions
- Dishes
- Freezers
- Liquid nitrogen
- Centrifuges
- Autoclave
- Vacuum ovens
- Cryotubes
- Microscopes
- ELISA-readers

CO_2 Incubators

- Water Jacketed CO_2 incubator
- 3 Gas/CO_2 Incubator with RH Control
  - Precise control of Oxygen levels combined with CO_2, and RH ensure accurate conditions for applications such as, hypoxic cell studies and cancer research.

Laminar Flow Hood

- HEPA filter rated at 99.99% efficient for 0.3 micron particulates. The HEPA filtered air is then directed vertically across the work surface.



Why hoods?

"Sitting or standing, wearing cleanroom garments, an individual will shed approximately 100,000 particles of 0.3um and larger per minute. The same person with only simple arm movement will emit 500,000 particles. Average arm and body movements with some slight leg movement will produce over 1,000,000 particles per minute; average walking pace 7,500,000 particles per minute; and walking fast 10,000,000 particles per minutes. Boisterous activity can result in the release of as many as $15x10^6$ to $30x10^6$ particles per minute into the cleanroom environment.'

http://www.lab.anhb.uwa.edu.au/hb313/main_pages/timetable/Tutorials/2008/3313%202008%20Tissue%20Culture.pdf

Dishes

- Dishes
- Multiwell plates
- Flasks

Freezers

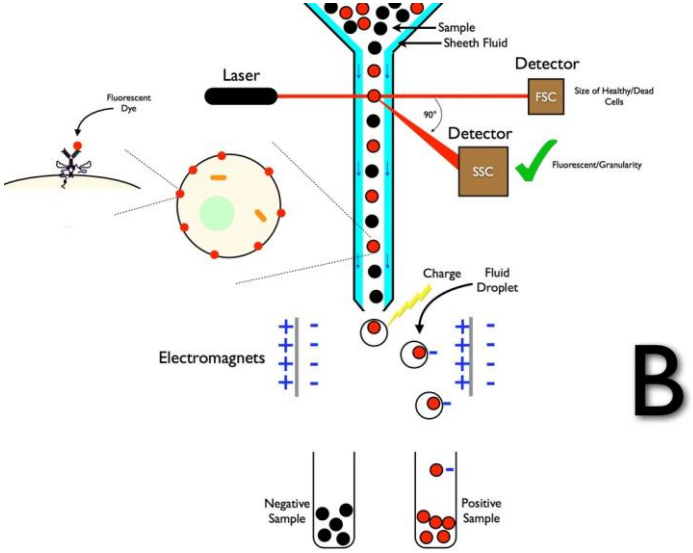
Centrifuges

Vacuum Ovens

Microscopes

ELISA readers

Flow Cytometer



B

Contamination

Minimise the risk

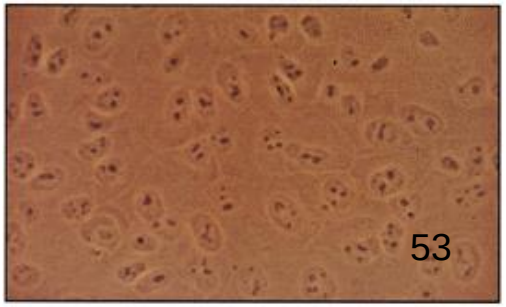
Cell culture- general

- Cell cultivation has to be carried out in a sterile environment to prevent contamination of the cultivated cells with bacteria or viruses.
- For this reason, cell cultivation is normally done in a separate lab, which is fitted especially for this purpose. The most important equipment is a sterile working place.

Contaminants of cell culture

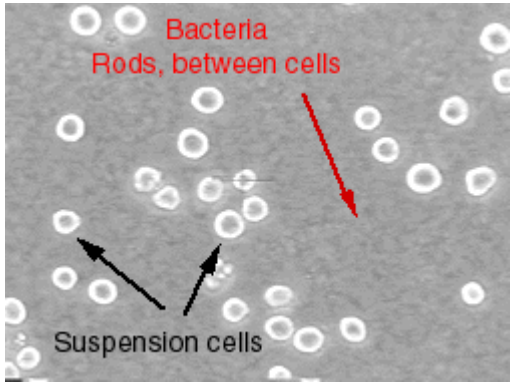
Cell culture contaminants of two types

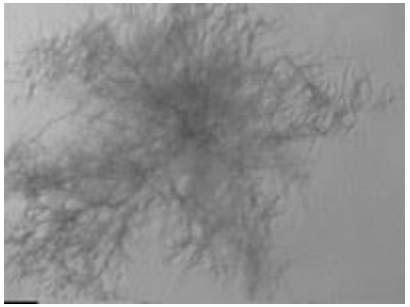
- Chemical-difficult to detect caused by endotoxins, plasticizers, metal ions or traces of disinfectants that are invisible
- Biological-cause visible effects on the culture they are mycoplasma, yeast, bacteria or fungus or also from cross-contamination of cells from other cell lines



Sources of Contamination

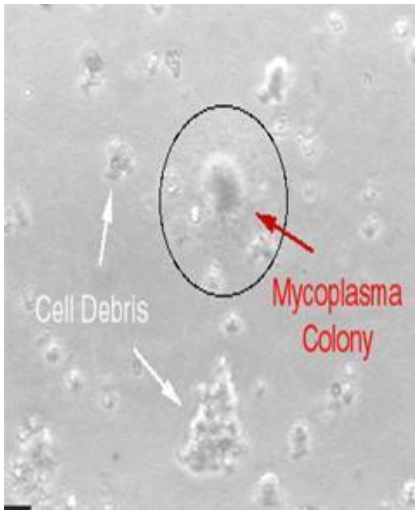
- Bacteria
- Fungi
- Yeast
- Mycoplasma
- Other cell types





Fungus

- Free organisms, dust particles or aerosols
- Surfaces or equipment



https://www.google.com/imgres

Class II Biological Safety Cabinet

Protection of
- **personnel**
- **environment**
- **product**

Class 1 Cabinets protect the product only

Cultivation of mammalian cells

Laminar flow box (Safety level 2)

•the constant air flow prevents particles from the room air coming near the working bench.
•The experiments as well as the experimenter are thus protected from being contaminated.

Cultivation of cells in incubators

- Cells should be cultivated under conditions as close to *in-vivo*- conditions. Therefore, special cell incubators are used. They provide constant temperature (37°C), in a humidified 5% CO_2 atmosphere (to provide constant pH via the CO_2/HCO_3-buffer system).

Mammalian cell Incubators --- provide optimal growth conditions

- CO_2 – incubators provide a humidified 5% CO_2 atmosphere at 37°C, which is optimal for cell growth.
- Growth media contain all necessary growth factors for the cells. Growth factors like amino acids or salts can be added through media additives.
- Generation time of mammalian cells: approx. 24 h

Safety….

Use of Cell Culture areas

- The cell culture area, as any other laboratory is a working area

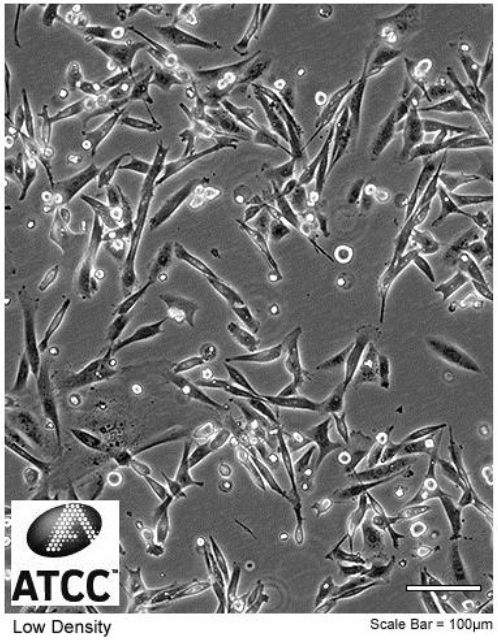
- Do not bring your friends in with you
- Do not eat, drink or smoke in these areas
- Do not use a mobile phone

- Do wear a lab coat at all times whether in a cell culture area or a laboratory
- Do wear disposable gloves, but make sure that you dispose of them in the correct way before you leave the area

- Do not wear disposable gloves in the corridors or write-up areas

Questions

What is the morphology type for following cells?



Cell line authentication is
a) the sum of studies demonstrating the lineage or identity of an animal cell and a lack of contamination.
b) having a written record of how you have grown your animal cells.
c) having some record of where your animal cells came from.
d) not necessary if your cells came from a primary culture.
e) not an important aspect of cell culture based studies.

Differentiate between Primary and Secondary cultures?

Explain the function of each of the following during cell culturing:
a) Basal media
c) Trypsin-EDTA (explain their individual function)

More resources..

Good cell culture Practice

https://www.youtube.com/watch?v=CA5fVLK5zAE&index=1&list=PLwjOK0qpGoI7sNU3ejrvUu2Y5yzR0SEw6

A collection of 9 videos from European Collection of Authenticated Cell Cultures (ECACC), especially videos 1, 2, 4, 5, 6