Compartmentalism of a Cell

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Rule To Build By:

To conduct multiple activities simultaneously, subdivide spaces and assign different functions to each space.

What:

There are many similarities between human built figures and those built by nature. With many activities happening at once in both a cell and in a medieval castle, both needed to break the subdivide spaces and assign different functions to each space (Morris, 2010). In a cell, the different functions necessary to carry out cellular life are distributed into different organelles, such as the nucleus and the mitochondria; in a castle, different activities are assigned to different rooms- dining room, kitchens and studies, among others. The palace can represent the cell as a whole, when breaking the castle into rooms as the cell distributes functions to organelles, and the castle can also represent just the nucleus, because the nucleus is the cell's command center just as castles ran all activities happening in their respective areas.

How:

The cell upholds the principles of compartmentalism well, having many different organelles for the different functions necessary for cellular life (figure 1). These organelles act as rooms for their specific responsibility within the cell: ATP synthesis occurs in the mitochondria, breakdown of unnecessary molecules is kept in lysosomes and peroxisomes, and cellular information is stored in the nucleus (Alberts, 2010). Even the plasma membrane has represents a function that a castle has, representing the walls or moat of a fortress, permeable only by that which belongs inside its confines. The only ways for materials to move into a cell are to pass through channels or ports specific to the small molecule, or to be endocytosed, via endosomes, if the cell needs the larger nutrients. This selective permeability keeps the cell safe from foreign bodies not targeted for the cytoplasm because without the right location sequences on any molecule, that molecule will not enter or leave the cell (Tamarkin, 2006). The nucleus acts as the eukaryotic cell's command center- where all genetic information is kept, where transcription and RNA processing and export, the first three steps of protein synthesis, occur and where DNA replication occurs prior to mitosis (Alberts, 2010) The nucleus itself is even compartmentalized, with the nucleolus as a sub-region housing the genes necessary for producing ribosomes (Davidson, 2005; figure 2). With all this information kept in the nucleus, it acts as the control center for the cell, with its own semi-permeable membrane, the nuclear envelope, that is accessible through nuclear pores and the rough endoplasmic reticulum (Alberts, 2010). Because all this information is stored in the nucleus, the cell's programming to carry out its functions lie inside the nucleus while the actual actions are distributed to their respective organelles as they are coded in the DNA.

Human built structures often carry out the principles of compartmentalism, even as early as castles in the eleventh century, as shown by Skipton Castle in North Yorkshire, UK (Skipton Castle, 2010). Skipton Castle has eighteen rooms, each serving different necessary purposes (3D Floor Plan, figure 4). With strong stone walls on the outside, the castle can be protected from attacks, the same way the plasma membrane protects the cell (figure 3). The castle originally had a drawbridge, adding to the selective entrance that the castle allowed (Skipton Castle, 2010). Inside the castle, there were guard towers, a dungeon, a banquet hall, bedrooms and other chambers for different purposes. The castle's head had multiple rooms to himself, be it for strategic planning or other actions necessary for the castle - much like a nucleus does for the cell.

Why:

Upholding the principles of compartmentalism has proved to be an evolutionary advantage, with the organelles of eukaryotic cells evolving from prokaryotes- cells with no nucleus or organelles (Alberts, 2010). The organization of

cellular functions into organelles helped for the evolution of multicellular life- prokaryotes are only found as single celled organisms. The eukaryotic nucleus evolved to keep nuclear chemistry separate from other cellular reactions (Pennisi, 2004). Similar to the nucleus's function, other organelles evolved to increase productivity: by dividing space into smaller compartments, the concentration of necessary molecules for the organelle's reaction rises, increasing the rate of reaction. The peroxisome shows this well because the cell keeps hydrogen peroxide inside the peroxisome, the degredation of unnecessary molecules or vesicles is much more efficient than if hydrogen peroxide were free in the cytoplasm. Simultaneously, there are genes being transcribed in the nucleus, proteins being translated by ribosomes, ATP being synthesized in the mitochondria, and cellular products being sent through the endoplasmic reticulum, endoplasmic reticulum-Golgi intermediate compartment and Golgi apparatus on the secretory pathway.

The plasma membrane is also advantageous because without some barrier from its environment, the cytoplasm would be exposed to many potentially harmful materials. Also, without this necessary protection there would be no cells at all as the cytoplasm from one cell would blend with all other cells in its area, making each cell a compartment (Alberts, 2010). The same structure of membrane, a phospholipid bilayer, is also responsible for containing the organelles within the cell. Each compartment has its own barrier, allowing for the reactions within the organelle to happen without interference. The compartmentalism of a eukaryotic cell proves to be evolutionary advantageous, more organized cells eventually led to multicellular life (Alberts, 2010).

Dividing a castle into many rooms also has its advantages. Without the rooms, all activities within the castles walls would be happening in one open space, resulting in a chaotic environment. The cooking would be kept in a kitchen, gatherings isolated to a meeting hall, and prisoners would be sequestered to the dungeon. A castle's walls also proved advantageous, both protecting the castle from intruders and by enclosing the castle from its environment by letting only what has permission to enter and exit through its doors, protecting the people and knowledge inside.

Figures:

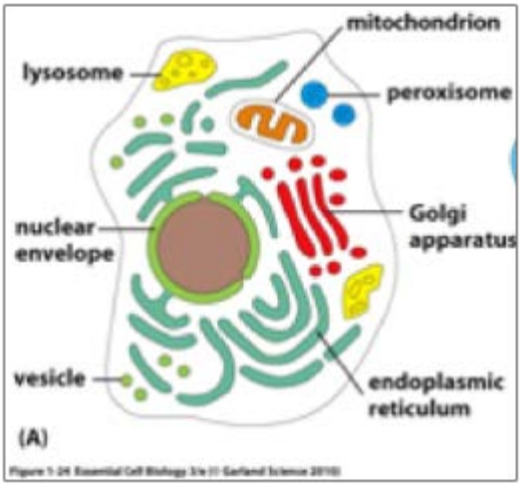

Figure 1- The cell is broken down in to many compartments, all of which contain a different set of reactions necessary to cellular life (Alberts, 2010 fig 1-24a)

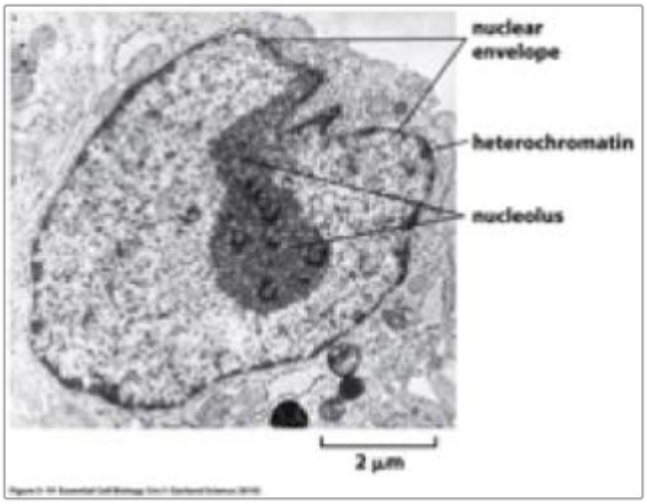

Figure 2- The nucleus has a sub region, the nucleolus, where the genes for ribosomal RNA are contained (Alberts, 2010 fig 5-19).


Figure 3- Skipton castle, showing one of the outer walls. The castle has two floors and the towers go to three floors (from http://www.simplygroups.co.uk/images/Skipton%20 Castle%20LR.jpg).

A

B

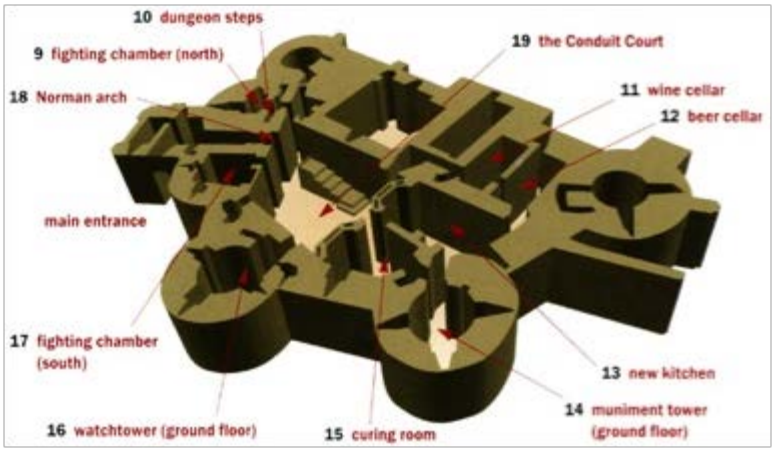

Fig 4- A three dimentional floor plan of Skipton Castle with (A) the second floor and (B) the ground floor. (From: http://www.skiptoncastle.co.uk/3dmap.asp)

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