CYCLONES

- BEFORE WE BEGIN, WE SHOULD KNOW WHAT IS THE DIFFERENCE BETWEEN AIR AND WIND

AIR & WIND

- **Air:** Air is the gaseous mixture.
- It includes oxygen, carbon dioxide and nitrogen.
- **Wind:** Horizontal motion of air caused by the pressure difference between two places.

- MOVEMENT OF AIR IS ALWAYS VERTICAL,
- ON THE OTHER HAND MOVEMEMNT OF WIND IS HORIZONTAL

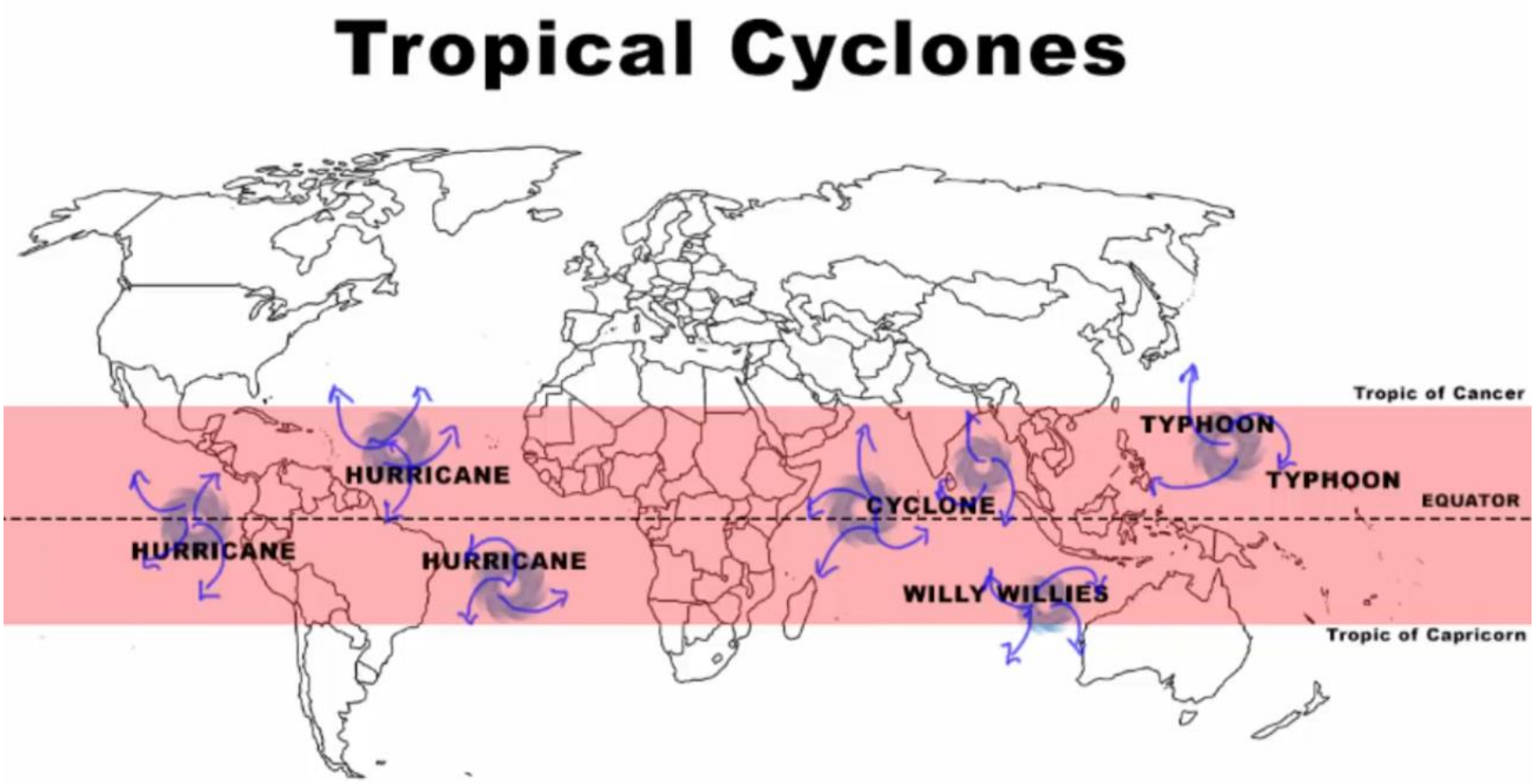
Classified according to wind speeds (miles/hour)

Tropical Depression - less than 39 m/h	Less than 62 Km/h
Tropical Storm - between 39 m/h and 73 m/h	63-118 Km/h
Tropical Cyclone - at least 74 m/h	EXCEEDS 119 Km/h

Cyclones are known by different names in different parts of the world:

- *Typhoons in the Northwest Pacific Ocean west of the dateline*
- *Hurricanes in the North Atlantic Ocean, the Northeast Pacific Ocean east of the dateline, or the South Pacific Ocean.*
- *Tropical cyclones - the Southwest Pacific Ocean and Southeast Indian Ocean.*
- *Severe cyclonic storm" (the North Indian Ocean)*
- *Tropical cyclone (the Southwest Indian Ocean)*
- *Willie-Willie in Australia*
- Tornado in South America

- A tropical cyclone brings very violent winds, torrential rain, high waves and, in some cases, very destructive storm surges and coastal flooding.
- Convectional rainfall is a type of rainfall that involves the formation of convection currents.
- The cyclonic rainfall, on the other hand, is caused due to cyclones



Cyclones are huge revolving storms caused by winds blowing around a central area of low atmospheric pressure.

Conditions to be satisfied for the formation of tropical cyclone

1. Warm ocean waters at least (26.5°C) to provide the heat. The warm sea water can evaporate more easily
2. Availability of moisture : Moisture is necessary for providing latent heat of condensation.

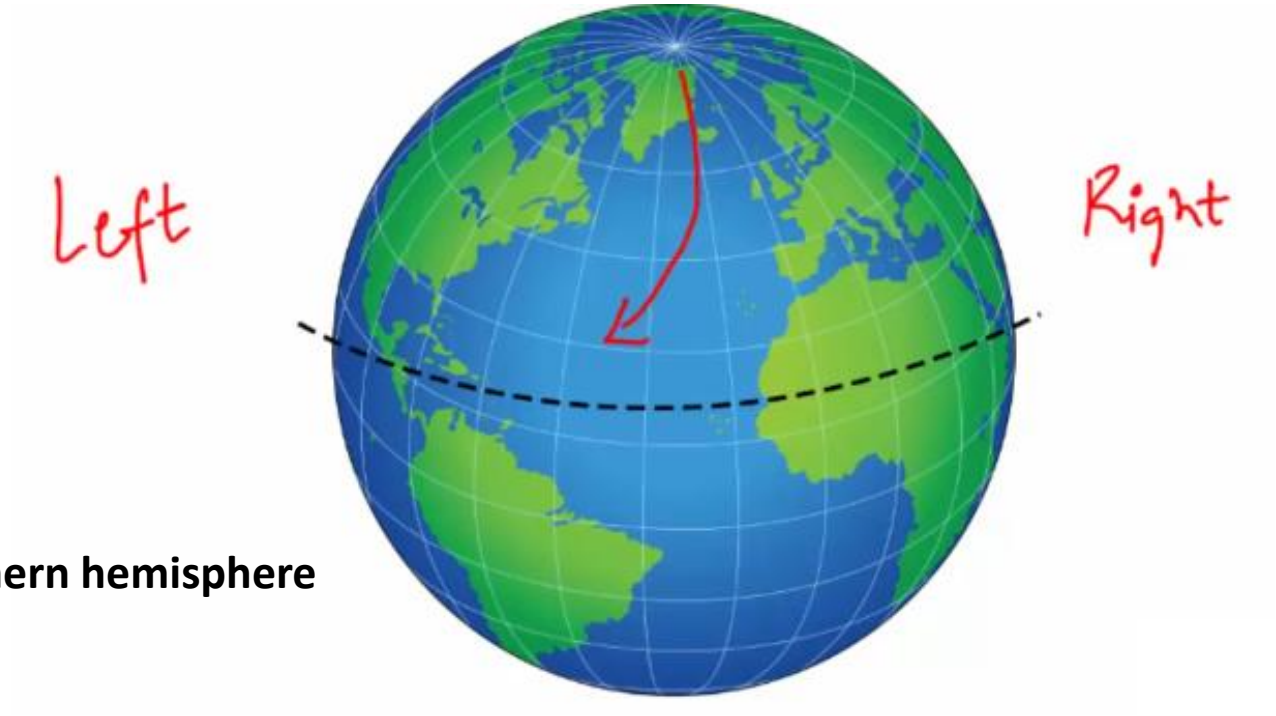
The less dense warm air rises over dense cool air. Warm air cools at higher altitude and moisture condenses to form huge clouds. Huge clouds form as the winds pick up moisture from the sea

3. Winds must be converging. Coriolis force to provide the rotation.

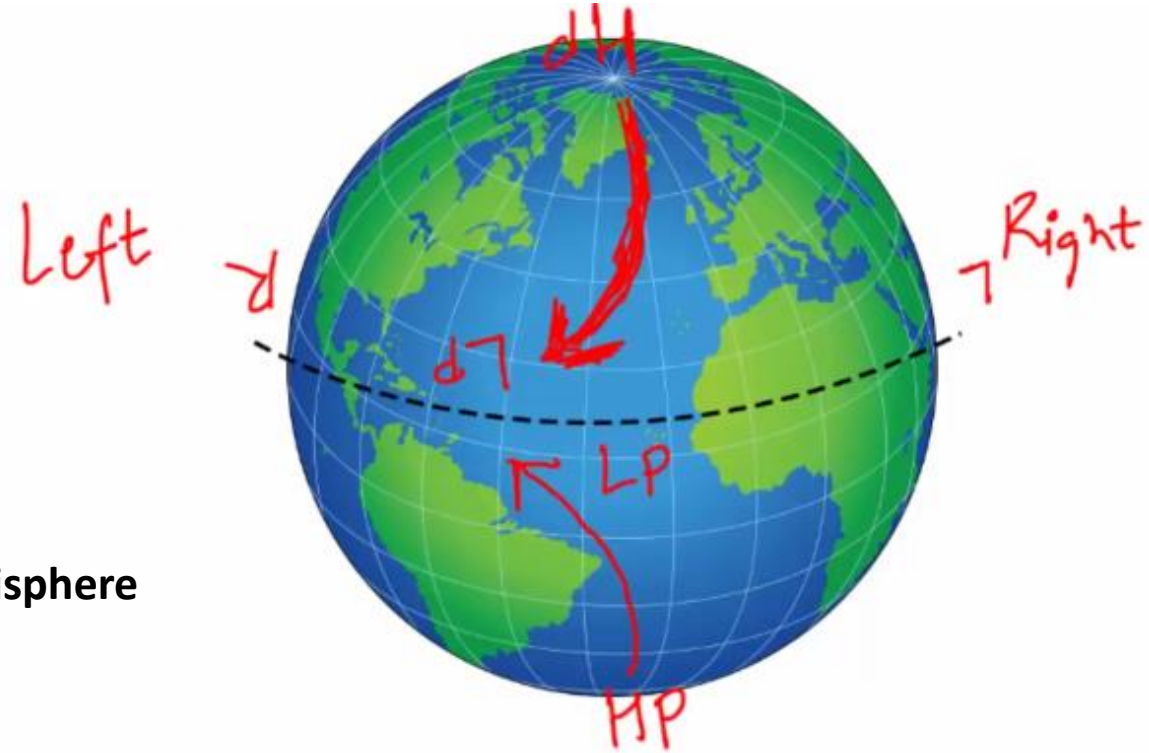
- Tropical cyclones don't form at the equator because equator to $\pm 10^{\circ}$ north/south, there is no Coriolis force.
- Coriolis force is zero at the equator and maximum at the poles (as it is directly proportional to the latitude angle) due to the rotation of earth (Earth moves west to east or westward).

Coriolis force leads to the formation of the cyclones

- EARTH SPINS on its axis, therefore, wind bends right or left from the direction of its flow. It follows that wind deviates from a straight path.
- In 1835, French mathematician Gustave Gaspard Coriolis discovered the force that bears his name, and derived the mathematical equations that describe the Coriolis Force.
- This force generates due to the rotation of Earth.
- If Earth did not spin on its axis, wind would blow following the Earth's curvature, with no deviation (no cyclone would exist). A wind blowing from south to north would not deviate northeast or northwest.
- Without the Coriolis effect air would *simply flow directly from areas of high pressure to areas of low pressure*.
- *At the equator, the Coriolis Force is nonexistent because wind does not* deflect at the equator as it does at the poles. At the equator, wind follows the Earth's curvature, without deviating right or left.
- Due to Coriolis Force at the equator, a hurricane or other tropical storm that formed in the north will not cross into the Southern Hemisphere, nor will one in the south cross into the Northern Hemisphere. The equator, therefore, acts as a barrier against the movement of tropical storms.

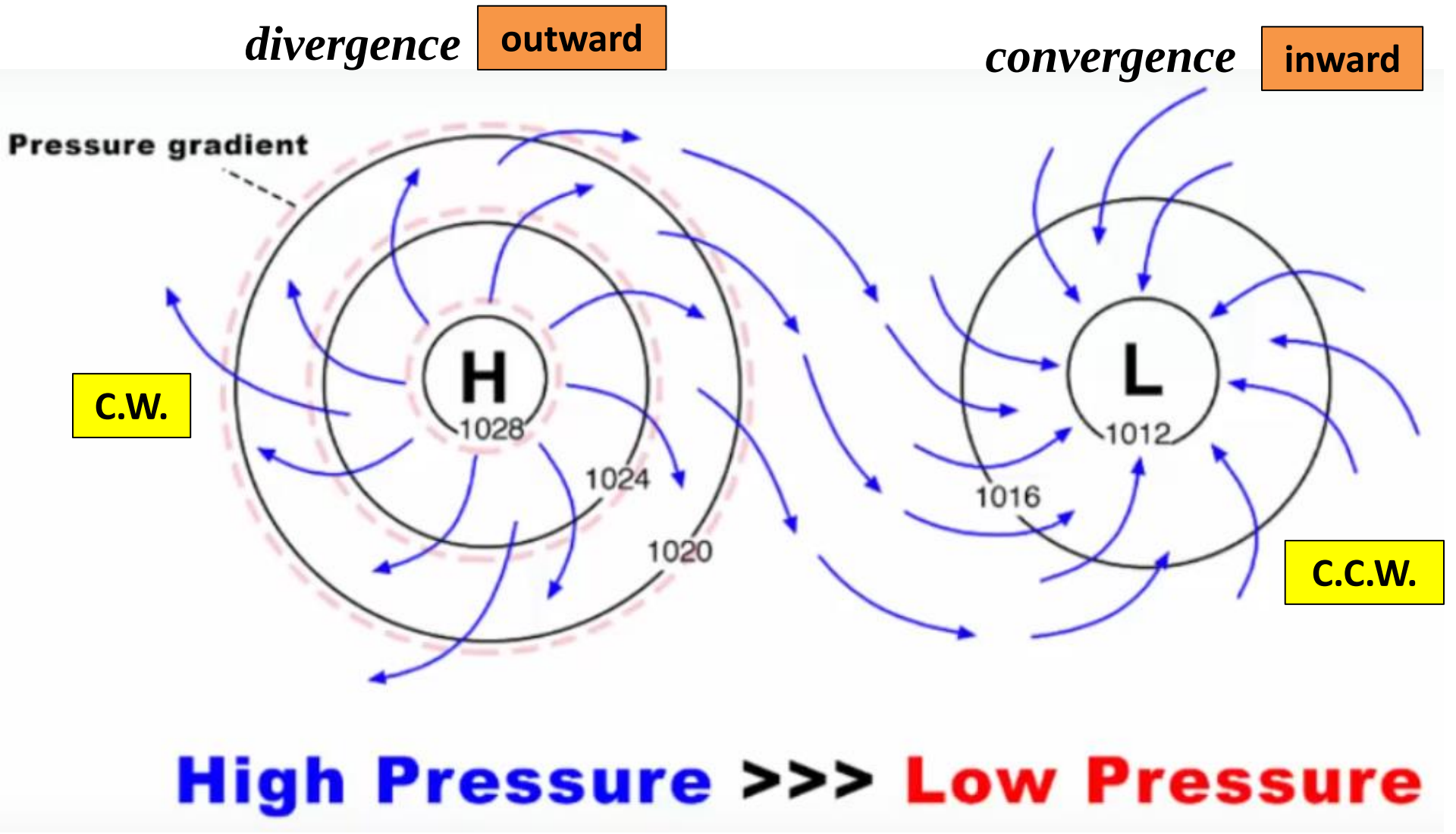


Northern hemisphere



Southern hemisphere

- So, we have learnt that the Coriolis force is what gives cyclones their spin .
- Without the Coriolis force, surface winds cannot gain sufficient rotation to converge (see the diagram below) and the low pressure of the disturbance cannot be maintained.



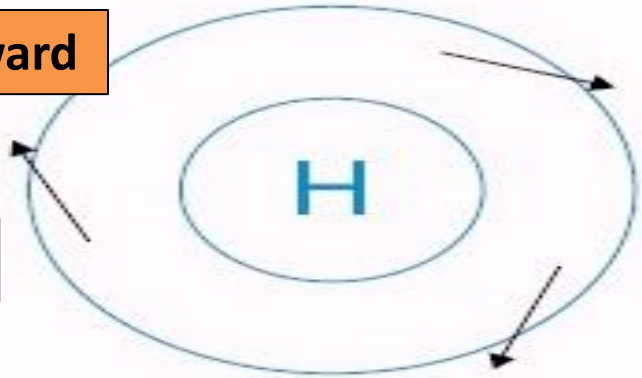
- Low Pressure Centers - In zones where air ascends, the air is less dense than its surroundings and this creates a center of low atmospheric pressure, or low pressure center (see the diagram above and below).
- Winds blow from areas of high pressure to areas of low pressure, and so the surface winds would tend to blow toward a low pressure center.
- But, because of the Coriolis Effect, these winds are deflected. In the northern hemisphere they are deflected to toward the right (which is why in the norther hemisphere, tropical cyclones moves from east to west driven by the global wind), and fail to arrive at the low pressure center, but instead circulate around it in a counter clockwise fashion as shown here.
- In the southern hemisphere the circulation around a low pressure center would be clockwise. Such winds are called cyclonic winds.

High & Low Pressure Cells

Surface winds blow clockwise around a high pressure and diverge.

outward

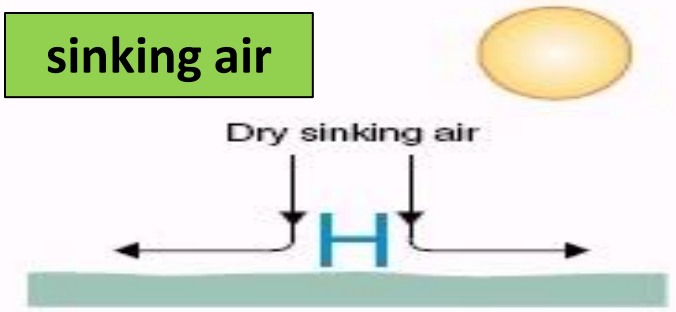
C.W.



View from above

clear skies

sinking air

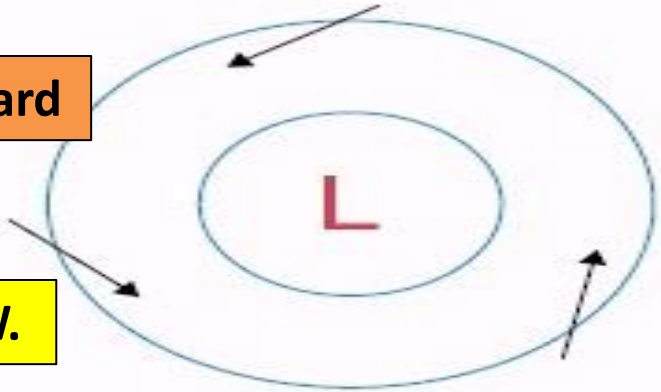


View from side

Surface winds blow counterclockwise around a low pressure and converge.

inward

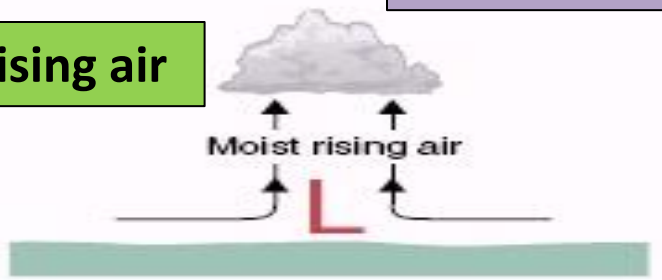
C.C.W.



View from above

cloudy skies

rising air



View from side

CONVERGENCE

Air in center RISES.

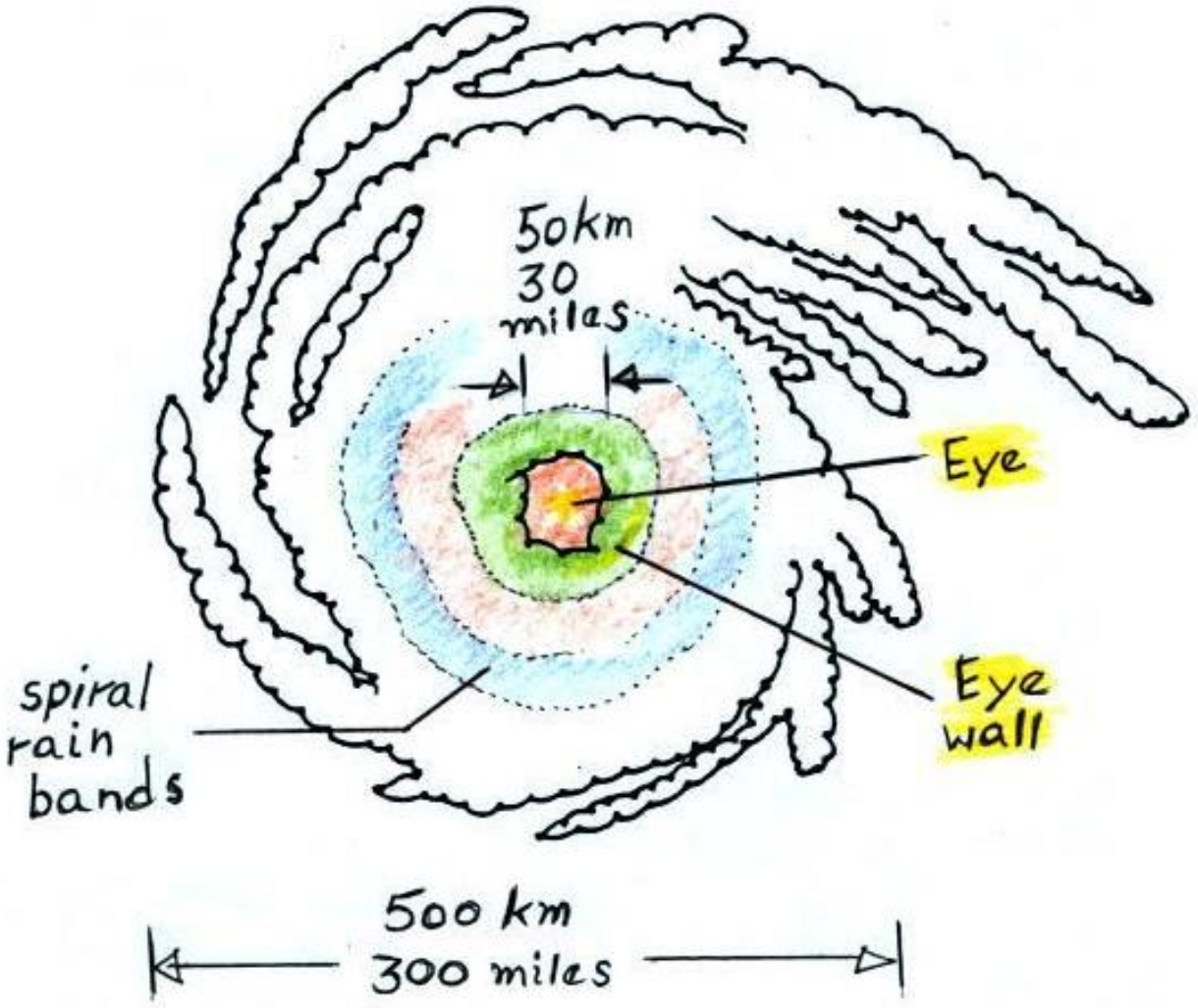
Rising air moves into lower pressure surroundings (at higher altitude), the air expands, expansion causes the air to cool. When you cool air to the clouds can form.

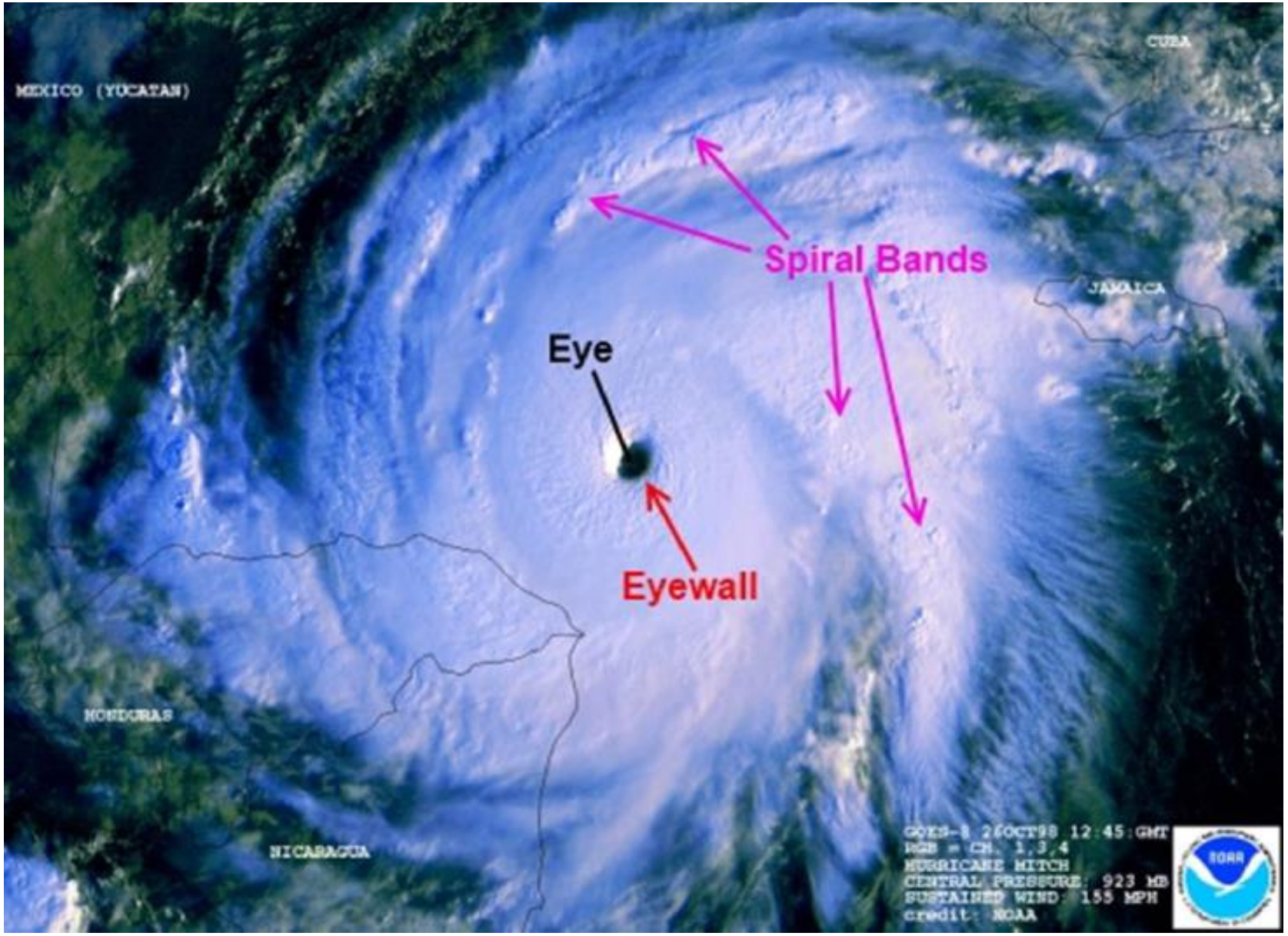
Formation of a tropical cyclone

- As air warms over the ocean, it expands, becomes lighter and force to rise. Other local winds blowing to fulfill the void created by the upward movement of the air. This air is also warmed and rises.
- The rising air contains huge amount of moisture evaporated from the ocean surface as it rises (evaporating water takes heat with it, that heat is stored in the wind), it cools, condensing to form huge cloud about 10 km up in the troposphere. Condensation means water vapour to liquid droplets.
- More warm air rushes in and rises draw by the draft above. and this creates a center of low atmospheric pressure, or low pressure center.
- The rising draft of air carry moisture high into the atmosphere, so that these could eventually become very thick and heavy. Therefore produces more and more thunderclouds.
- But that's the only beginning. The Coriolis force causes the rising currents of air to spiral around the centre of the tropical cyclone. The winds spiraling around this central core create the eye of the tropical cyclone and eventually spread out at high altitudes.
- Condensation releases the latent heat energy stored in the water vapor, which further warms the troposphere. Eventually, some of the relatively warm air above the eye begins to sink into the central core.

- And the majority of the released latent heat escapes to the space as infrared radiation.
- This dry descending air within the eye gives the core a clear, cloud free sky, with little to no wind and sometimes the sun can be seen.
- At the eye, cyclones increases its speed, because of angular momentum.
- In the eye wall air ascends from the surface to the tropopause. Pressure gradient is the strongest near the eye wall, where the most violent winds are produced. relatively low wind speed in the eye.
- Strongest rainfall is also produced in the eye wall. Strongest storm surge occurs to the right of the hurricane.
- Tropical cyclones derive their energy from the latent heat of condensation which made them exist only over the oceans and die out rapidly on land.

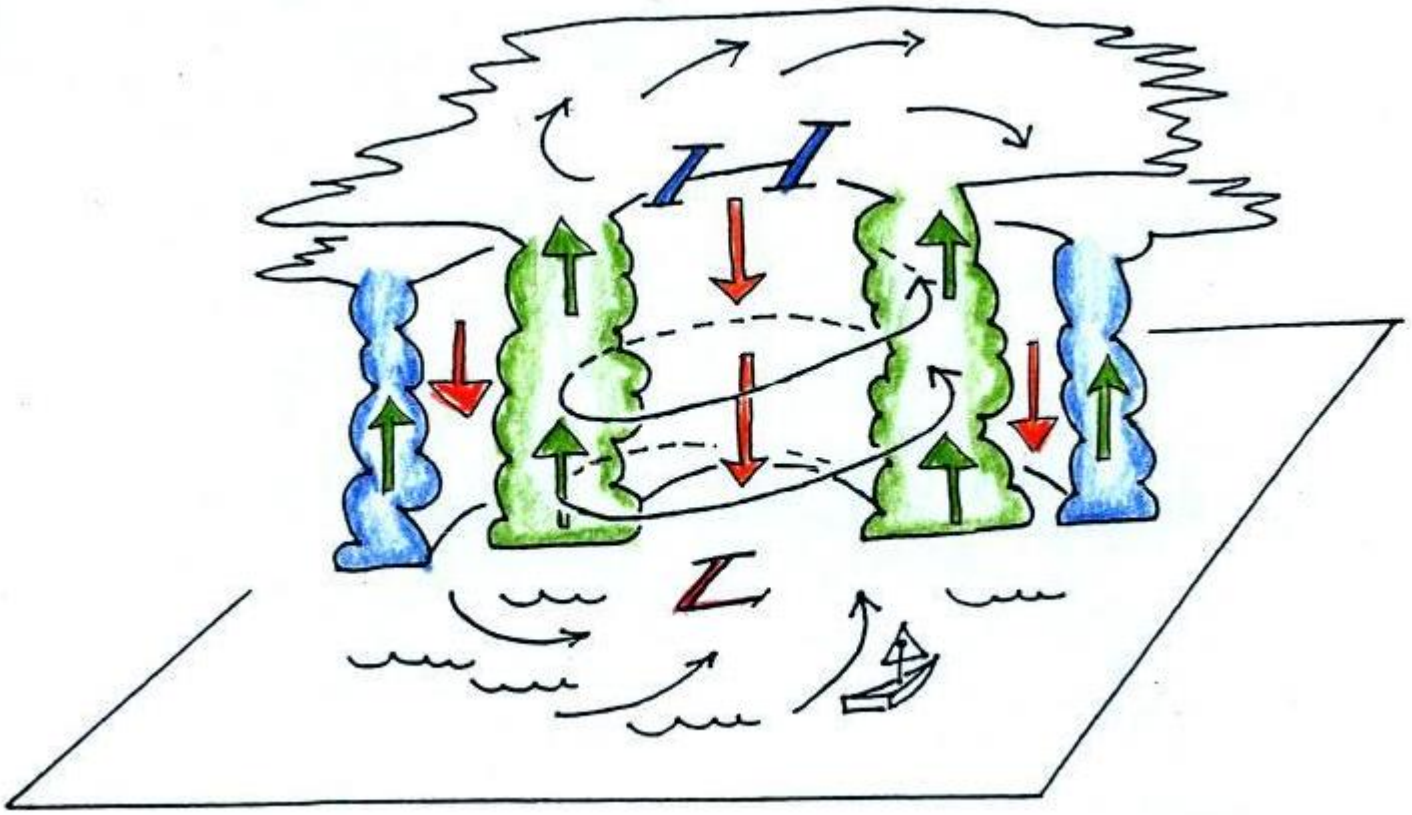
Structure of a tropical cyclone – an eye, eye wall and spiral bands





Hurricane Mitch (1998) captured on satellite by the National Oceanic Atmospheric Administration (NOAA) over the Atlantic Basin. This Category 5 monster of a storm reached max sustained wind speeds of 180 mph and caused around $6.2 billion in damages. Source: NOAA

- Although tropical cyclones come in many different categories and sizes, their structure is the same.
- The three main features of a hurricane are the eye, eye wall, and rain bands.
- Eye of Cyclone : The eye is most spectacular part of a matured cyclonic storm which is situated in the center, is a relatively calm, clear area usually 20-40 miles (about 10 to 50 km). It is a calm region with practically no rain.
- It has the lowest surface pressure value within the storm and can grow or shrink as the storm strengthens or weakens. Most people assume the eye to be the worst part of the storm, but that's not the case. Smaller the eye, the stronger the storm.
- It resembles an 'eye' when viewed in a satellite picture.
- The eye is the region of the lowest pressure at the surface (The cyclone's lowest barometric pressure occurs in the eye).
- Eye is warmer than the surrounding region and warmest temperatures aloft (in the upper levels). The eye temperature may be 10°C to 16°C warmer (release of latent heat of condensation) at an altitude of 12 km to 16 km than the surrounding environment, but only 0-4°C warmer than its distant surroundings near the surface. Therefore, a tropical cyclone is a warm core system surrounded by cooler air.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- Eyewall: Surrounding the eye is the eyewall, a wall of thunderclouds.
- The eye is surrounded by a thick wall clouds around it. In other words, a ring of cumulonimbus clouds that swirl around the eye.
- The eyewall has the most rain and the strongest winds of the storm, gusting up to 225 mph (360 km/h) in severe storms.
- This is where the cyclone's strongest winds and the heaviest rains are found, making it the most dangerous part of the storm. The height of the wall goes up to 10 to 15 km.
- Rain Bands: Located just past the eye wall are the rain bands that radiate outward and form the outer most fringes of the storm. They are characterized as long, arching bands of clouds and thunderstorms. Not all rain bands are the same length.
- Rain bands within tropical cyclone are curved in orientation. The extent of rain bands around a tropical cyclone can help determine the cyclone's intensity.
- These bands are sometimes hundreds of kilometres long and a few kilometres wide. Thunderstorms are observed here.

In a nutshell -

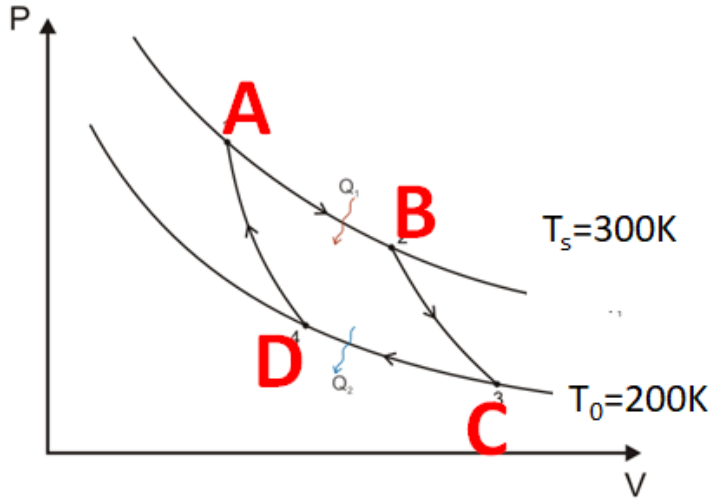
To form, a cyclone needs warm ocean winds, moisture and Coriolis force for the winds. The Coriolis force (generates due to rotation of the earth) rotates the winds in such a manner that wind always towards the LP centre directly, but aren't able to reach it, but get deflected. So, all the strong winds from HP zone rushing in towards the LP zone gets converged…..rotate (spin) around the centre. The surface winds rotates on right (to the west) in northern hemisphere and on left (to the east) in southern hemisphere.

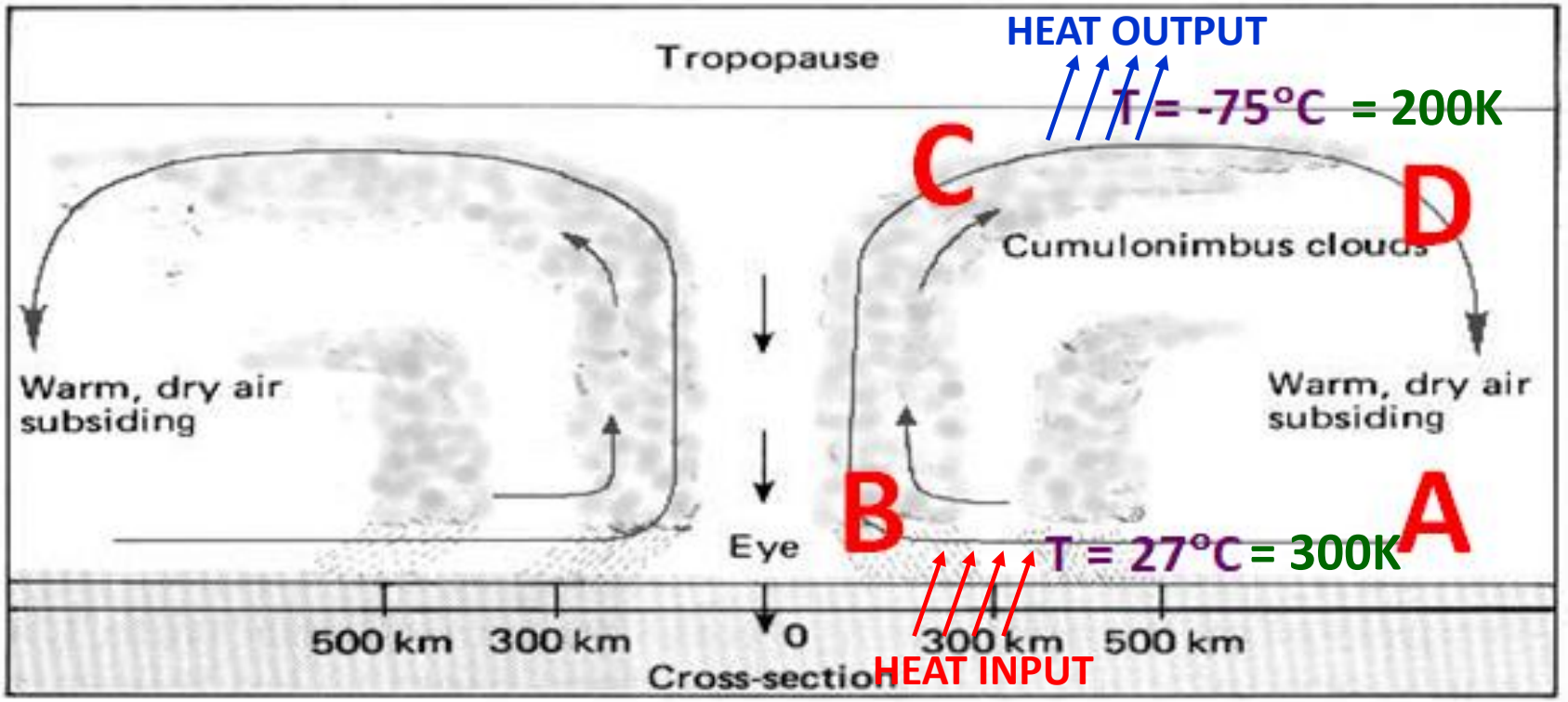
Therefore, we have learnt that the Coriolis force spins the cyclones ie., the Coriolis effect causes a hurricane to move in a circle. Tropical cyclones rotate clockwise in the Southern hemisphere and counterclockwise in the Northern hemisphere.

The centre of the cyclone is referred to as the eye of the cyclone with little to no rain and clear skies. This area has the lowest surface pressure in the storm and warmer temperature (very less amount of warm air descend in it from troposphere). The area around the eye (eye wall) has the strongest winds, heaviest rains and the most cloudy skies. An average hurricane can carry more than a 100 billion pounds of water.

Cyclones can’t form too close to equator, because there is not enough difference in rotation, so not able to starts them spinning.

PV-Diagram of the hurricane Carnot engine





Schematic representation of a hurricane as a heat engine

- Tropical cyclones work somewhat like engines, not the engine in your car, but an ideal gas.
- Namely, tropical cyclones extract heat from the ocean. The ocean is a giant heat reservoir (act as the hot reservoir) that has been absorbing sunlight all Summer and early Fall. This is the reason why warm, deep sea-surface temperatures (60m or deeper) are needed for tropical cyclones.
- A cyclone has a warm front and a cold front with a substantial difference in the temperatures. Colder upper atmosphere acts as a sink.
- There is an intake system (the atmospheric boundary layer) that draws in the fuel (warm, humid air). The engine (thunderstorms) converts heat into mechanical energy (winds and waves). And there is an exhaust system (precipitation fallout for water and anvil blowout for air) for the spent fuel.

$A \rightarrow B$: air undergoes isothermal expansion as it flows toward the lower pressure (high volume) of the storm center while in contact with the surface of the ocean (heat bath @ $T_s \approx 300K$). Evaporating water takes heat with it, that heat is stored in the wind, so temp stays the same even the pressure goes down.

$B \rightarrow C$: Moist air rises (very fast ascent of air happens) adiabatically in the eyewall thunderstorms. At C, low pressure as compared to that of B.

C→D: wind flows out (almost at a constant elevation, hence temperature remains constant) to the upper layer of troposphere and isothermal compression takes place at very low temp, ≈200K) - water vapour condensed to form thunderstorm, thereby volume is reduced. Latent heat of condensation is released, which is why top of the hurricane is warmer. At point D, vol is reduced as compared to at point C (gaseous state to liquid state phase change occurs).

The cooling of water in the troposphere also releases a lot of heat. This heat transfer creates enough energy to cause strong winds.

D→A: Finally dry air (after loosing its water molecules in the troposphere) sinks back to the ocean surface kept compressing (surface pressure is high as compare to that at high elevation in the troposphere) and getting warmer (ocean surface temp is much higher than that of troposphere). The cyclone engine is ready for another cycle and can get larger and larger.

A tropical cyclone consumes same amount of power as the entire US.

Table 7.1: The Saffir-Simpson Hurricane Severity Scale

Tropical Cyclone Classification	Wind Speed			
	meters per second (m/s)	knots (kn)	miles per hour (mph)	kilometers per hour (km/h)
Hurricane Category 5	≥ 70 m/s	≥ 137 kn	≥ 157 mph	≥ 252 km/h
Hurricane Category 4	58–70 m/s	113–136 kn	130–156 mph	209–251 km/h
Hurricane Category 3	50–58 m/s	96–112 kn	111–129 mph	178–208 km/h
Hurricane Category 2	43–49 m/s	83–95 kn	96–110 mph	154–177 km/h
Hurricane Category 1	33–42 m/s	64–82 kn	74–95 mph	119–153 km/h
Tropical Storm	18–32 m/s	34–63 kn	39–73 mph	63–118 km/h
Tropical Depression	≤ 17 m/s	≤ 33 kn	≤ 38 mph	≤ 62 km/h

m/s column is imp

Preparedness

- Vulnerability Analysis and Mapping to include Resources.
- Assess strengthening requirements and execute.
- Funding for preparedness must be arranged.
- Peoples' cooperation through Political leaders, elders, Volunteers and NGOs
- Plan to include movement of resources with time frame.
- Aim to reduce the destructive potential of cyclones, timely & appropriate relief to victims and quick & durable recovery

Only for your information

Disaster Preparedness Framework

COMPONENTS OF PREPAREDNESS		
Vulnerability Assessment	Planning	Institutional Framework
Information System	Resource Base	Warning Systems
Response Mechanisms	Public Education and Training	Rehearsals

Only for your information

- Understanding the way that people are killed and injured in a particular disaster is a best way for reducing casualties.
- Mitigation is planned after studying the elements at risk.
- Mitigation also helps in the protection of the economy from disasters and reduce the risk within limit of socio economic conditions through proper planning and decision making. .
- Creating awareness of risk is the main role in Mitigation process.
- Decision makers plays a major role as they have to assess the losses faced by the country and have to make important decisions to reduce further losses.
- The very big challenge for the people and government is to cope with the adversity of an unpredictable destruction with courage.

Only for your information

The immediate challenge is to find answers to the following questions

- What is the actual situation in the affected areas?
- Where are the survivors and how to bring back their day to day life?
- What are the facilities required in disaster prone areas?
- How effective are the rehabilitation measures?
- What are the techniques for confronting future disaster related problems?

Management of cyclone : Cyclone response activities

Structural measures

- Developing shelter belts:

Shelter belts with plantations of trees can act as effective wind-and tide-breakers. Apart from acting as effective windbreakers and protecting soil crops from being damaged, they also prevent soil erosion.

- Land use control and settlement planning:

Ideally, no residential and industrial units should be permitted in the coastal belt of 5 km from the sea, as it is the most vulnerable belt. No further growth of settlements in this region should be permitted. Major settlements and other important establishments should be located beyond 10 km from the sea.

- Developing community cyclone shelters:

- Cyclone shelters at strategic locations can help in minimizing the loss of human life. In the normal course of life, these shelters can be used as public utility buildings.
- Construction of permanent houses: There is a need to build appropriately-designed concrete houses that can withstand high winds and tidal waves.

Management of cyclone : Cyclone response activities

Non-structural measures

- Involve community through Training & education and strengthening them:

Spreading awareness and train local people/volunteers/police by NDRF & SDRF regarding preparedness through repetitive mock drills, training, and distribution of ready relief material bags.

- Targeting schools, colleges and all educational institutions is a very important part of awareness generation.
- It has to be sustained through constant updating, upgrading and mock drills.

- Installation Of Earth Warning Systems :

- Such systems fitted along the coastlines can greatly assist forecasting techniques, thus helping in early evacuation of people in the storm surge areas.
- Developing communication infrastructure Amateur Radio has today emerged as second line unconventional communications systems and is an important tool for disaster mitigation.

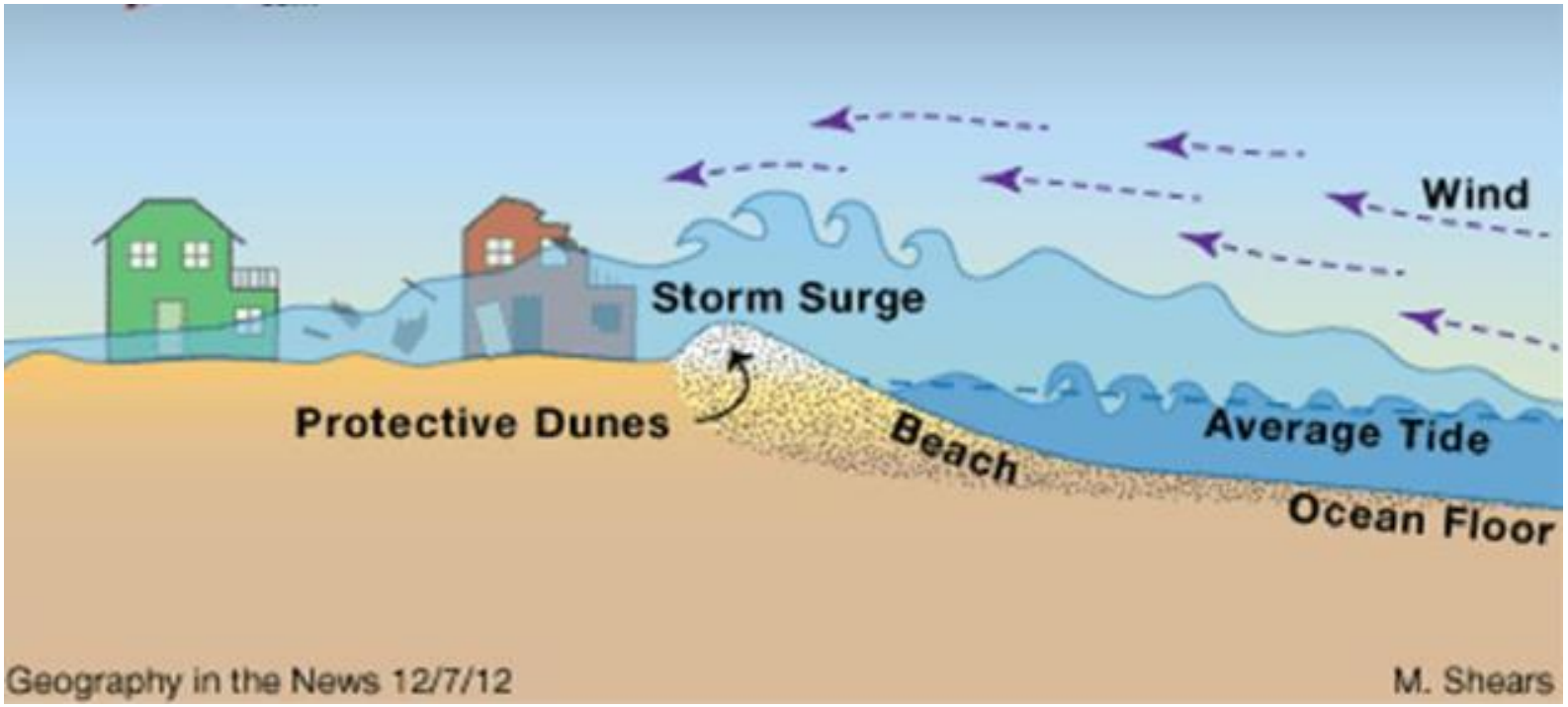
- Medical preparedness :

Surge prone coasts of India

- ❑ Storm surge heights depend on the intensity of the cyclone.
- ❑ Elevation of the total sea level increases when peak surge occurs at the time of high tide.
- ‘The Storm surge associated with a cyclonic storm, responsible for 80% loss of human lives, occurs in the eye wall region’.
- A storm surge happens because of the winds of the storm interacting with the ocean's surface. The low pressure and strong winds lead to the water level being changed on coming in contact with the shore. The water levels rise because of the strength of the winds and then the water is pushed in the direction of the winds. This causes the sea level to rise abnormally because of the storm, known as a storm surge.
- The highest surge tends to occur near where the strongest winds of the storm occur. Faster the winds, more severe is the storm surge. In the worst case scenario, a storm surge can coincide with a high tide and raise the sea level by a lot.

Go through it, but no need to memorize line by line

- Vulnerability to storm surges is not uniform along Indian coasts. The following segments of the east coast of India are most vulnerable to high surges
  i) North Orissa, and West Bengal coasts.
  ii) Andhra Pradesh coast between Ongole and Machilipatnam.
  iii) Tamil Nadu coast, south of Nagapatnam.
- The West coast of India is less vulnerable to storm surges than the east coast of India in terms of both the height of storm surge as well as frequency of occurrence.
- However, the following segments are vulnerable to significant surges :
  i) Maharashtra coast, and ii) adjoining south Gujarat coast and the coastal



- Storm surges are notorious for flooding. Faster winds will result in a more severe storm surge.
- Storm surges are very destructive and can lead to extensive loss of property and life. Some impacts of storm surges are:
- 1) Unexpected flooding. The excess rise of sea level can lead to flooding in nearby coastal areas.

  2) Destruction of infrastructure. Roads, buildings etc are destroyed in the case of strong surges.

3) Ruin of soil. As storm-surges have saltwater content, if they reach the agricultural lands, they can decrease soil fertility. Fauna and flora both stand at a risk in storm surges.

4) Loss of life. People can be caught unaware of the storm surge and lose their near and dear ones. Storm surges can also contaminate these areas with chemicals leading to long-term problems.

5) Devastation of crop, increased prices for food, unemployment, loss of livelihood may results in increased crimes in the society.

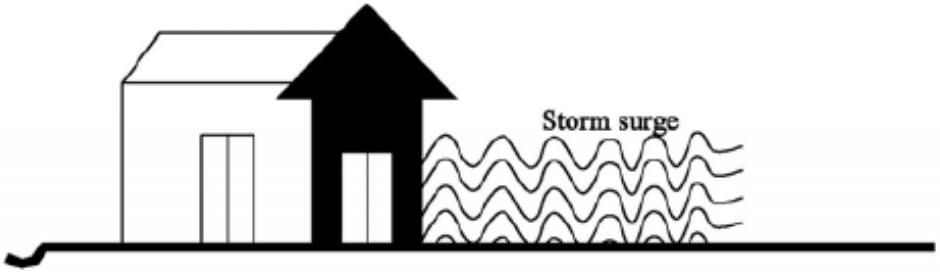
6) Food scarcity is the main impact of cyclone as they loss their agricultural supplies.

List of major tropical cyclones that affected India in recent time:

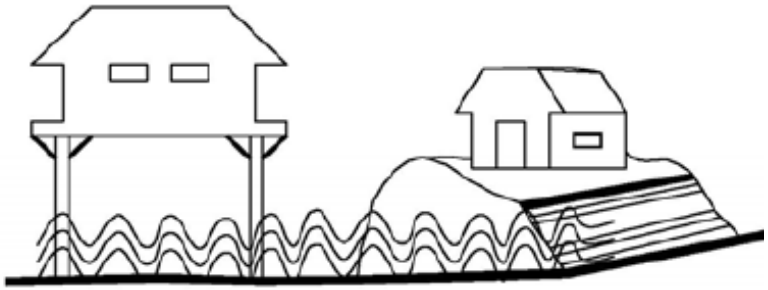
- Cyclone Aila that lashed India's east coast in 2009
- Three severe cyclones in a row - Phailin in Odisha (2013), Hudhud in Andhra Pradesh (2014), and now Vardah in Tamil Nadu
- Very Severe Cyclonic Storm (VSCS) Hudhud hit the east coast at Vishakhapatnam in Oct, 2014
- Cyclone Titli hit the coastal states of Odisha and Andhra Pradesh in Oct 2018
- Extremely severe cyclonic Fani hit the Odisha coast in Puri early in May 2019
- Super-cyclone Amphan hits coast of India and Bangladesh in May 2020
- Cyclone Nisarga has made a landfall near Mumbai on June 3, 2020

Cyclones Safe Design and Construction

- The roofing materials used commonly in the coastal regions of India are (a) Thatch, (b) clay tiles, (c) asbestos cement or metal sheets and (d) reinforced cement concrete. These roofing materials are easily blown away during the cyclone, so must be avoided.
- In cyclonic regions, close to the coast, a site above the likely inundation (more) level should be given preference.
- For individual buildings, a circular or polygonal plan shape is preferred over rectangular or square plans.
- Wall openings - doors and windows should have strong closing/locking arrangements and glass/wooden panels be securely fixed.
- Glass panelling - provide proper locking arrangements of shutters. Securely fix the frames to walls.



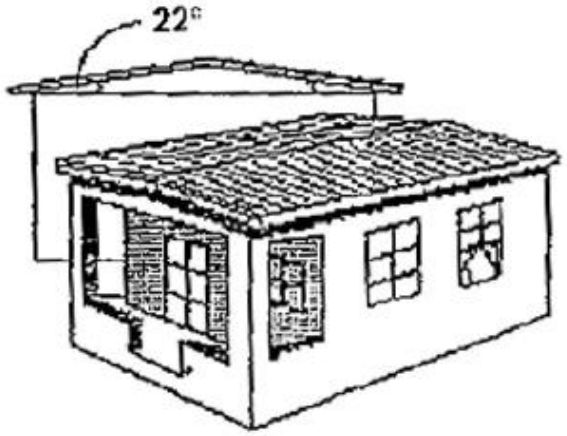
Construction at ground level risk of inundation



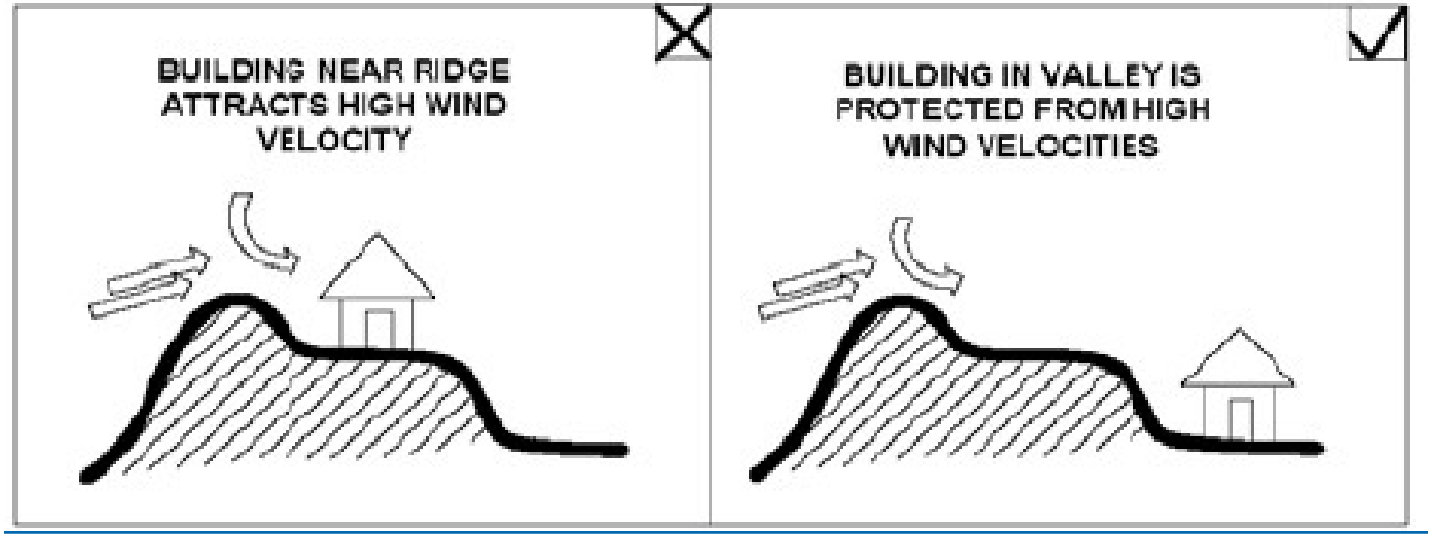
Construction on stilts or artificially raised earth mounds

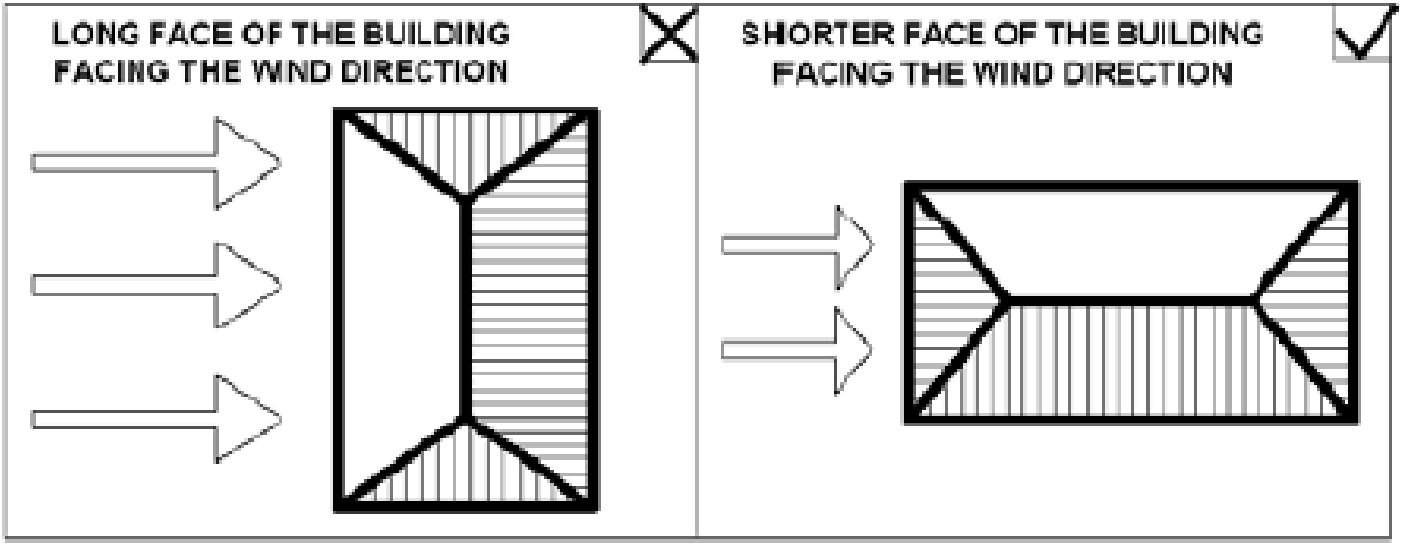
Diagrams are imp

Lightweight flat roofs are easily blown off in high winds. In order to lessen the effect of the uplifting forces on the roof, the roof Pitch should not be less than 22°. Hip roofs are best, they have been found to be more cyclone resistant than gable roofs.



Flat Roof





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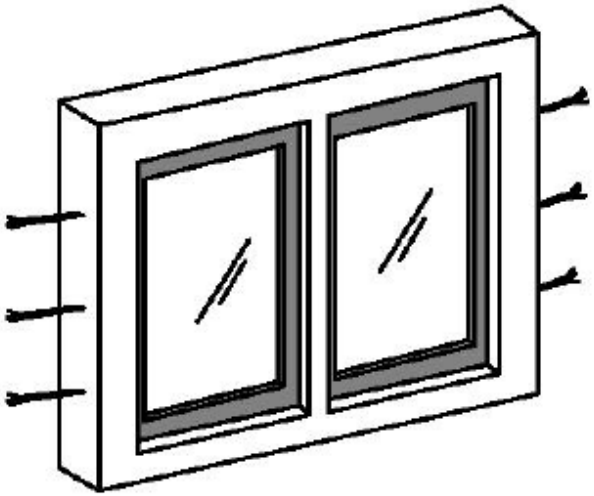
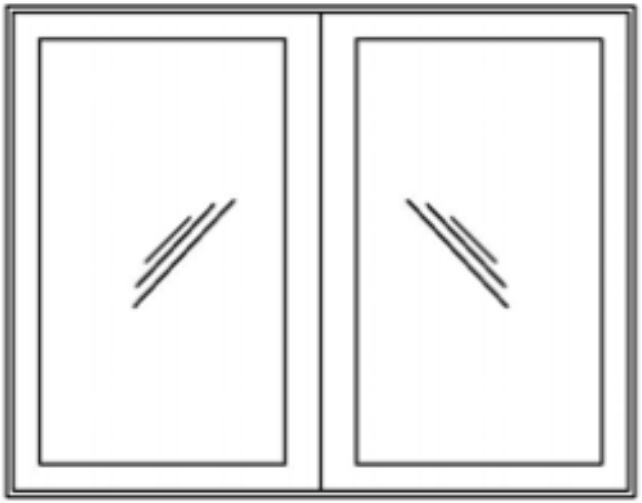
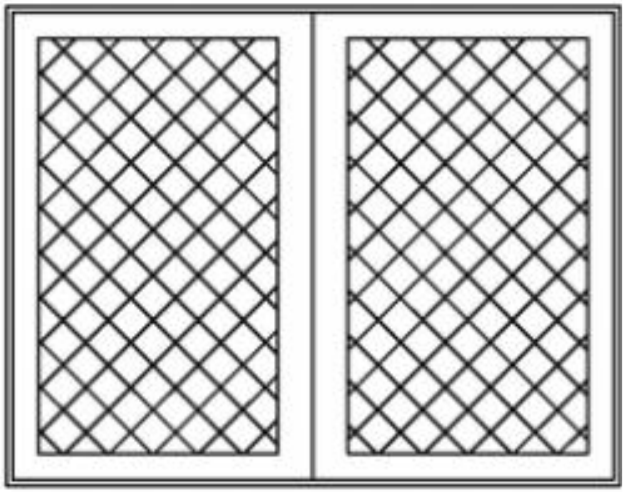


Adequate anchorage of door and window frames with holders



Large and thin unprotected glass areas in windows



Also glass panes can be strengthened by pasting thin film or paper strips. It will introduce some damping in the glass panels and reduce their vibrations.

During disaster

a) Cautionary advice put out on social platforms urging people to stay safe can reduce the number of casualties.

b) Social media and the Internet, speedy official and community messages, creating online groups and sharing messages offering help and advice.

c) Delivery of food and health care via mobile hospitals, with priorities to women child & elders.

d) Protection of the community and their evacuation and quicker response.

Go through it, but no need to memorize line by line

Post disaster

- To overcome the power cut it is important to have rooftop solar and battery storage systems as supplementary power sources.
- Planting trees with strong root systems and pruning the canopy ahead of cyclone season could reduce uprooting.
- Government should restore infrastructure and provide priority relief to the families of those who lost their lives, and the worst-hit communities.
- Efficient use of technology and implementation of the Sendai framework is the need to the hour
- Collaboration with other countries in the region to strengthen the cooperation and efforts and to make a common fund for disaster management.
- Providing alternative means of communication, energy and transport just after the disaster.
- By taking long and short term mitigation measures, the loss of life and property can be minimized.

Go through it, but no need to memorize line by line

How to protect yourself-

- If you are in car, remain in the car, stop driving.
- move away from electric poles, trees etc.
- Close doors & windows
- switch off electric appliances and stay in home.
- Keep a note of all the warnings given by the Meteorological Department.
- Keep emergency phone numbers of police, ambulance and fire brigade handy.
- Move people and valuable items to a safe place.

Only for your information

Impacts of Cyclone

- Cyclone cannot be prevented, but their impact on people's lives can be reduced to a considerable extent.
- Disaster management covers all aspects of preventive and protective measures, preparedness, rescue, relief and rehabilitation operations.
- Impacts of cyclone effects economy, social and cultural activities of people and county. Some of the major impacts are as follows,
- The impact of tropical cyclone destruction on the society as been so large and do not affect people equally. Cyclone mostly affects coastal districts. Several people in coastal villages who depended only on fishing are among most vulnerable communities.
- Several tropical cyclones are responsible for large number of damage to properties and resources of the country.
- Collapse of buildings, accidents and disease from contaminated food in the post cyclone period is also the reason for loss of life.
- Cyclone may result in heavy rainfall and floods which is the next devastation to the environment can cause water log in unwanted places which causes many diseases.
- Almost everything is destroyed and thousands of people are left homeless due to cyclone.

Go through it, but no need to memorize line by line