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"Can Vernacular Architecture in the Tropics assist with Modern Passive[1] Ventilation Design in Domestic Buildings?"

Introduction:

Since the boom in Air Conditioners (AC) after the WWII, architects began to move away from passive cooling techniques and relied on AC to achieve thermal comfort. Air conditioning was marketed as improving personal health, improving sleep and keeping homes clean (Gissen D. 2003) and we began to see sealed concrete boxes replacing the vernacular architectural styles of the tropics.

Not only are air conditioners high-energy consumers therefore expensive to run (particularly problematic for many developing nations) they also spread dirt particles, micro-organisms, bacteria and germs if not properly maintained.[2] (Wolfgang L., 2005.) With depleting energy reserves causing a significant rise in fuel costs, there is an increasing pressure to reconsider passive techniques as a 'free and readily available' option when it comes to cooling buildings.

This essay relates to Unit A4 in that it rethinks techniques to achieve thermal comfort through efficient means, or as appropriately stated by Z.M.Zain, (2007) *"[considers] effective strategies to overcome the state of discomfort with minimum energy utilization."*

The Investigation

With a much-needed shift from mechanical to passive cooling in today's architecture, it is valuable to reconsider tropical vernacular and question whether it can assist with passive cooling techniques used today.

It could be argued that thermal comfort in the tropics can be achieved at much higher ambient temperatures and humidity levels because of occupants acclimatization, however, the vernacular understanding of optimum designs in hot humid environments combined with present day technological advances and 'knowledge' should only be advantageous. Or has the demand for convenience and technological developments advanced above the vernacular?

This investigation explores the indigenous architecture of the West Indies, Malaysia and Pacific. Although the vernacular is native to each region, there are enough similarities in their architecture to define 'tropical vernacular' for the purpose of this assignment. The study attempts to draw comparisons between tropical vernacular and modern passive cooling techniques whilst evaluating arguments for and against the question in hand.

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[1] Defined by Givoni as *"…simple cooling techniques that enable the indoor temperature of the building to be lowered through the use of natural energy sources...including a fan or a pump where the application may be enhanced."*

[2] *"….about 42% of the perceived pollution in a modern office building comes from the AC system"* (Less is More, Thermie Programme Action, European Commission Directorate-General for Energy, cited in Holger K.N. 2002, p119)

The Tropical Climate
The tropics lie along the equator, between 23º and -23º latitude and can be distinguished by hot humid conditions. Mean annual temperatures reach a maximum of 30ºC during the day and 24ºC at night, however, diurnal ranges tend to be low, ranging approx. 8ºC. Humidity levels vary between 60% - 100% and a tropical climate is accompanied with a high levels of rainfall, during 'rainy periods' where annual mean rainfall can exceed1000mm. Monsoons, hurricanes and earthquakes are also typical in a tropical environment. (Adapted from Lauber W. and Koch-Nielsen H)

The main stresses of this climate are high humidity levels, temperatures and solar radiation. Humidity reduces cooling via evaporation as the air is already saturated, so by ventilating a space, the saturated air is removed, increasing the rate of evaporation and convection that dissipates heat from the body, building structure and fabric. Solar shading is also an efficient means of keeping cool however, due to the limited nature of this assignment, ventilation is the focus of this study.

Characteristics of Tropical Vernacular Architecture
Untutored builders of the vernacular had an admirable talent for suiting buildings to their environment. An extensive knowledge of the climate and ability to modify their buildings meant various ventilation techniques for cooling and reducing solar gains were incorporated into building designs.

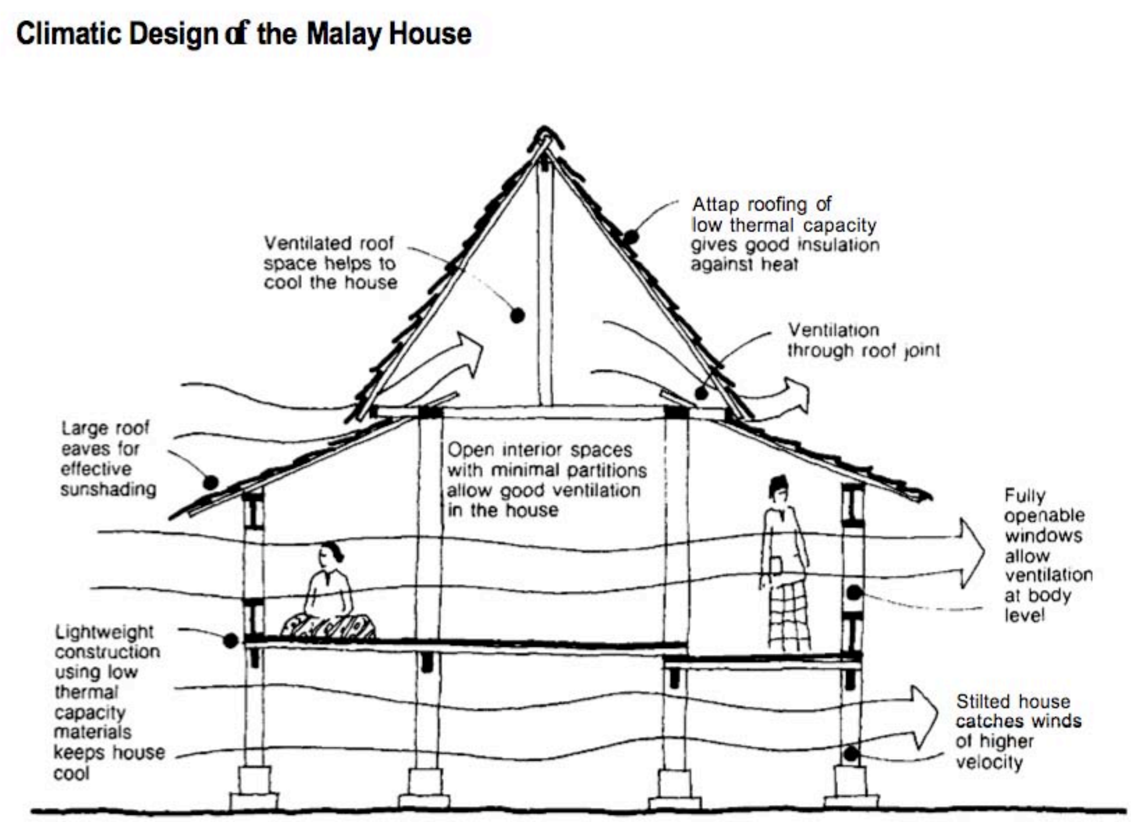

Fig. 1*"….the near perfect house form which is appropriate to local climate" (*Yuan L. J.)

Locating
Tropical vernacular homes were located in areas of dense vegetation with overhanging trees that could shade the building whilst creating a cooler microclimate.
They were orientated towards prevailing winds to optimize cross ventilation; in the instance of Micronesia, homes faced towards the ocean to maximize sea breezes.

Shape and Form
An elongated floor plan and minimum internal partitions created an easy passage for cross ventilation by reducing friction and fig. 1 indicates how this technique was repeated beneath the house by raising it on stilts. Although this is an example of a Malaysian home, is also evident in the West Indian and Pacific home, initially intended to prevent flooding. Not only did this help to catch winds of a higher velocity, by shading the ground the air underneath was cooled and drawn up through the floorboards.

A high ceiling, typical in tropical vernacular, shows an understanding of the stack effect. Hot air rises with buoyancy and is infiltrated out via ventilation roof joints or in the instance of the Malay funnels shaped roof (*bumbung panjang*) via grills at each gable end, otherwise referred to as Jalousie Louvres in the West Indies.

Solar gains were reduced in the Malay home by large roof overhang and the West Indians used verandahs (after the European Influence). Both techniques allowed windows to remain open so that ventilation could still infiltrate the building during rain periods.

The Samoan home of the Pacific initially had no walls allowing breezes to flow freely; (windows were a later European influence.) In the Malayan home, windows were plentiful, placed to maximize cross ventilation. They were full length, casement windows, designed to cool at body level; the most important cooling area. West Indian homes tended to have smaller openings by comparison, the intention being to reduce solar gains. However, cross ventilation was still a priority.

Materials
In all instances local materials were used, what was closest to hand and readily available. This was typically timer and palms. Timber, a lightweight material was generally used for walls and floors and thatch was used on the roof, both providing good insulation from solar gains being materials of a low thermal capacity. In the instance of the *Mbure,* a type of vernacular specific to Pacific, walls were made from woven reed and could be rolled down when privacy was required without blocking ventilation.

In most instances, materials and forms have been adapted over the years because of external influences – migration, invasion etc (see fig 2). Timber walls were replaced with concrete and wooden shutters became glass or single hung windows, however these adaptations do not necessarily denote beneficial developments, particularly regarding ventilation; Le Roux refers to them simply as over-glorified techniques of the west.

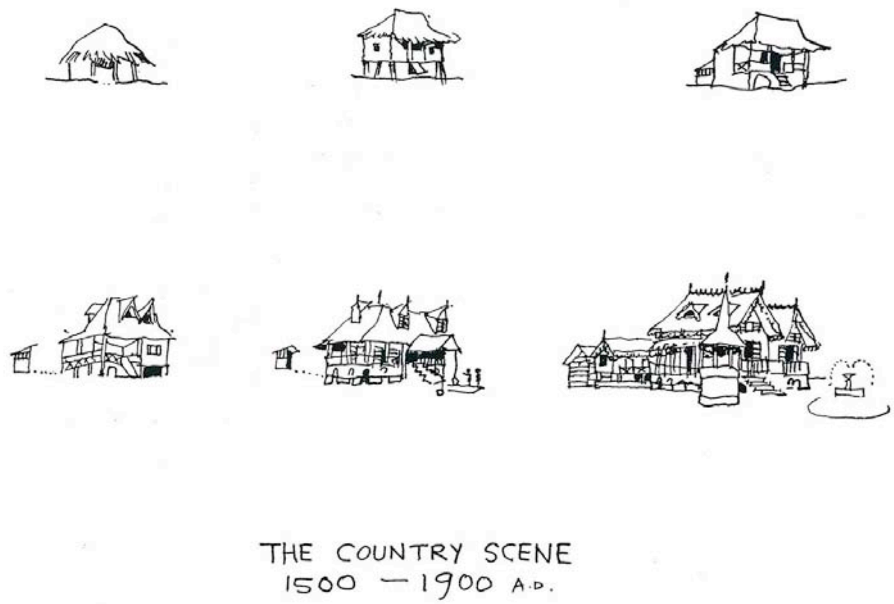

Fig. 2 *The development of the West Indian house 1500 – 1900 (Ajoupa* – Newel Lewis J. 1983)

Vernacular cooling techniques in the present day context

"Today, great architecture is also designed by instinct and… in unison with nature. The high technology and complicated materialism is just an enormous mantle, which clothes the idea. Underneath, the instinctive solution is still there." Le Corbusier (cited in Newel Lewis J. (1983)

The vernacular is designed by immediate response and has had the fortunate ability to be modified according to suit the occupants thermal needs, resulting in practical and non-stylistic buildings. Le Corbusier's quote indicates how these vernacular techniques need to be in place before any additional 'complexes' are added

Direct Application:

There is no reason why passive-cooling techniques taken directly from the vernacular, cannot be used in present day residential design. Orientating buildings towards breezes for optimum comfort ventilation; raising buildings on stilts, maximizing the stack effect; creating the opportunity for cross ventilation and using water and vegetation to create cooler microclimates (see fig. 3) are all cost effective methods that can be implemented during the design process. Murcutts example of a Northern Territory home (fig 4) appears to achieve many of these vernacular characteristics.

Fig. 3 *MVRDV 3-D Garden; Multistory Apartments; Netherlands (Big and Green, D. Gissen 2003, p96.)* A direct application of a vernacular principle; cooling the breeze before it enters the domestic environment.

Fig. 4 *Glen Murcutt; Marika Alderton House, Australia, 1991-4 (Lauber W. 2005 p146-7.)* A vernacular design in a current context.

Materials:

The replacement of timber walls with concrete in the 1800's shows a shift from a lightweight material to one with a high thermal capacity. In a hot humid climate with a low diurnal temperature, this is very inappropriate; the thermal resistivity of timber is 10 times greater than concrete[3] although, thermal comfort is not the only practical factor to consider. In some countries such as Malaysia, Yuan claims that timber is being exported at such a rate that it is diminishing internally and becoming too expensive for locals. Timbers that do not contain large amounts of tannin, can present termite problems

[3] The thermal resistivity of timber = 6.93 m2 deg ºC/Wm whereas concrete is 0.69 m2 deg ºC/Wm (Module A2 study book, 2007, p166)

(Lauber W. 2005 p113) and its lightweight qualities can be problematic during a hurricane or cyclone. In this instance, concrete is the most appropriate material. Tropical homes have also seen the replacement of a traditional thatch roof with zinc or galvanized iron. Although more durable, the latter materials heat up tremendously during the day whereas thatch is a very good insulator.

These two examples reveal that there has recently been a higher priority applied to durability as opposed to thermal qualities in materials. L J Yuan rightly claims, *"[n]ew indigenous materials… should…be developed to supplement and stimulate the indigenous building industry."* If we can replicate the *Mbure* wall for example, that allows for privacy, shading and ventilation but use technology to enhance its durable qualities, adaptive opportunities (controlling volumes of ventilation) and safety considerations, then a combination of both vernacular and present day can produce highly efficient materials designed to optimize ventilation. (See fig 5)

Fig. 5 *Glen Murcutt; Marika Alderton House, Australia, 1991-4 (Lauber W. 2005 p146-7)*
The present day *Mbure* Wall?

Or perhaps rethinking the application of 'old' materials is first required? An example being 36-37 Squadron Headquarters RAAF, Richmond, Australia. Holes were bored into the concrete floor slab, not only encouraging airflow through the slab, but reducing the overall mass of the structural form too (see fig. 6) This commercial application could easily be applied to a residential situation.

Fig. 6 *Bligh Voller Nield Architecture; 36-37 Squadron Headquarters RAAF, Richmond, Australia, 2006 (courtesy of Bligh Voller Nield)*

Developing materials may also help to over come a social problem, which can inhibit the use of vernacular materials. In Malaysia, the vernacular tends to be associated to lower class living; homeowners would rather own a concrete, air-conditioned home than a timber equivalent, because of the prestigious value.

Stimulated Natural Ventilation:

The following examples appear to have developed from the vernacular principles of ventilative cooling, but use components to further enhance the cooling effects. In some examples, simple mechanical devices are or can be used to enhance the effective cooling, control and direct wind flow or used when there is little available ventilation.

1. Direct Ground Cooling:

Even in a hot humid climate, the earth surrounding the building can act as a direct passive cooling source. If shaded by the underside of the raised home and cooled by summer rains (instigating evaporation,) a 10-12ºK difference in maximum air and earth temperatures can be achieved. (Givoni B. 1994 *Florida Study*)

This coolth can significantly reduce the temperature of ventilation and by installing PVC air pipes and stylizing simple mechanical devices (fans), the effects can be made more efficient. This cooled ventilation can be introduced into the building (see fig 7a) or the warm internal air can be re-circulated into the ground. (Fig 7b)

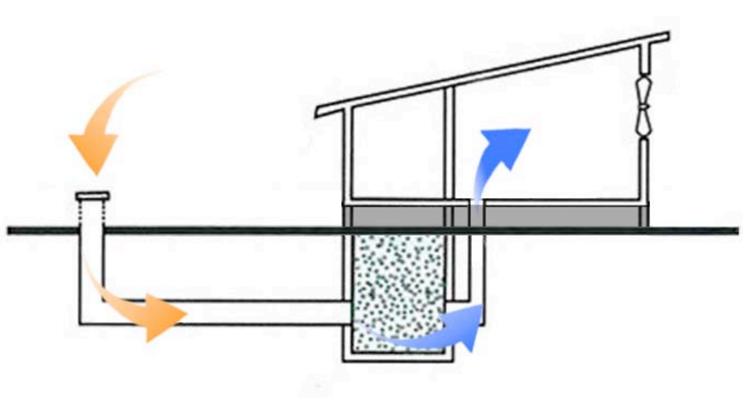

Fig. 7a *Direct Ground Cooling (adapted from Koch-Nielsen H. 2002, p135)*

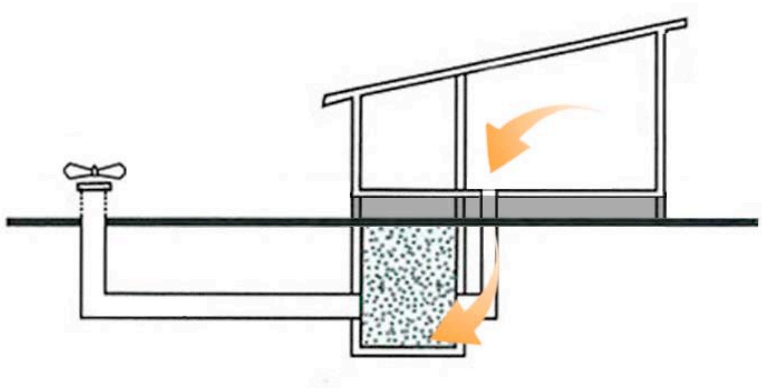

Fig. 7b *Direct Ground Cooling – Earth as a heat sink (adapted from Koch-Nielsen H. 2002, p135)*

2. Indirect Evaporative Cooling:
Ventilation can also be cooled by indirect evaporation before being entering a building, using a water reservoir (tank, roof pond) heat exchanger (matting, concrete slab) and a simple fan to control this cooling technique (see fig 8.) Via convection currents and long wave radiation, the cooled heat exchanger reduces temperatures of the interior space without effecting levels of humidity. (See fig 8)

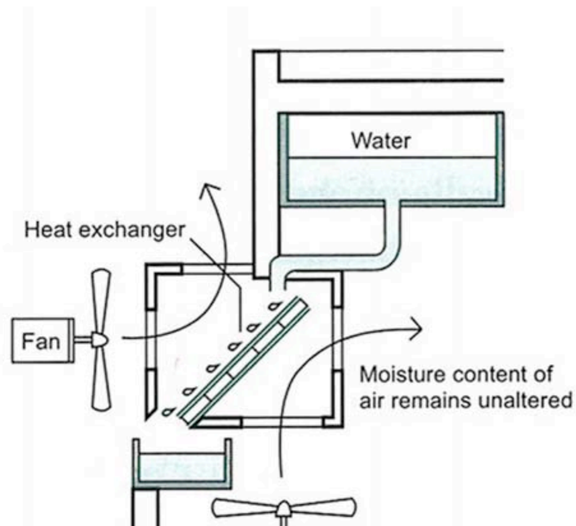

Fig. 8 *Indirect Evaporative Cooling (Koch-Nielsen H. 2002, p133)*

3. Roof Ventilation Devices:
A solar chimney is a sophisticated device that enhances the stack effect. (See fig 9) Although it cannot independently generate enough air movement to cool the body, it expels hot unwanted air from an interior space, which is as critical. By painting the metal chimney black, the air temperature inside increases causing a suction effect and draws the internal air from the space, up and out the chimney.

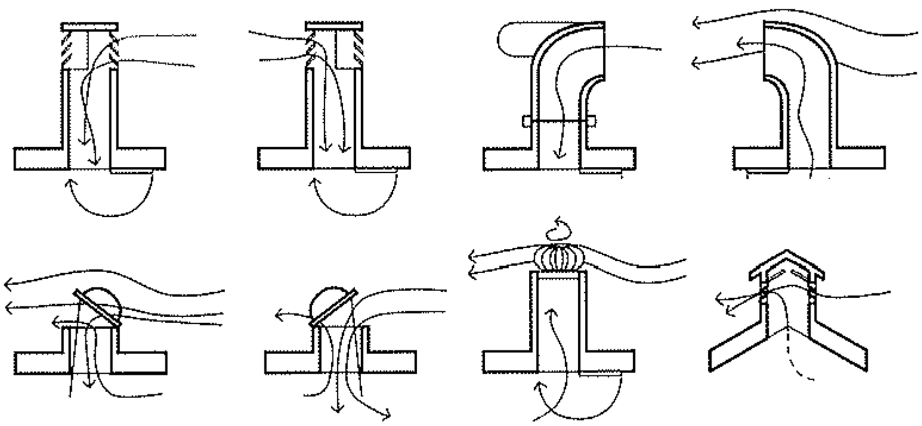

Fig. 9 *Roof Ventilation devices (Koch-Nielsen H. 2002, p129)*

Mechanical Cooling:
We need to be reminded that '*forced ventilation should only be used to compensate for climatic impacts rather than poor buildings design*'. (Koch-Nielsen H. 2002.) The above principles should be applied and if thermal comfort is still not achieved, only then should mechanical cooling devices used. This may be the only solution for residences in a dense urban situation where the Heat Island Effect results in higher temperatures or ventilation is limited. Issues such as safety, pollution, space restrictions, and costs can reduce the effectiveness of cooling, as the openness required to optimize ventilation cannot always be achieved. Adjacent high-rise buildings may block or divert airflow and high land values may dissuade developers to create a microclimate (vertical gardens for example), which occupy valuable square footage. Low energy buildings can be more costly during design phase, particularly if Computer Fluid Dynamics are used to predict climate behavior, but this is recovered during running costs. Unfortunately, through experience, this happens to be frequently overlooked by clients.

The Malaysian Architect, Ken Yeang, stated in the Far Eastern Review that AC cannot be abandoned in the tropics but passive techniques can reduce the need for mechanical cooling devices. Initially, this appears ideal, however, combining ventilative cooling with AC is problematic as the appropriate design principles for each circumstances are quite opposing. Naturally ventilated buildings require maximum ventilation, large openings and surface area, whereas AC is most efficient when ventilation is minimized, openings are small and the building is compact (see Appendix fig. 10.) If both techniques are combined, the architect runs into the danger of neither the passive or mechanical cooling techniques achieving maximum efficiency. Instead, design for the most intended used.

Conclusion
The vernacular has been developed over many centuries therefore particularly fine-tuned to our climatic needs. Not only can it assist with modern passive techniques, but it can and should be applied directly at any available opportunity. Comfort ventilation and the stack effect form the bases of most modern ventilation cooling techniques when considering ground cooling, indirect evaporative cooling and solar chimneys. With the implementation of modern materials and applications, the ventilative cooling technique can be made more effective.

It appears forgotten knowledge is fortunately being re-learnt and with this, we need to recognize the potential of passive cooling techniques whilst reduce the reliance on AC. Technology is here, it can work to enhance the vernacular and the combination should be embraced to achieve the optimum. *"This can be and has to be done by not copying / faking the old designs but drawing lessons recognizing the values and reinterpreting them in the present context."* (Vernacular Architecture in Queensland, Australia.) However in some situations, some compromises need to be made and if these means the implementation of mechanical devices, the occupant should ensure these are powered by renewables and designed to maximize efficiency.

Limitations

Due to a word restriction, the author assumes the reader has previous knowledge of this subject matter. It is also the reason for a lack of discussion regarding social and economic factors associated with the passive cooling which also influence the question in hand. The ideas discussed in this assignment need to be explored further with these factors in mind and with consideration to commercial buildings too.

Implications – Existing orthodoxy and Wider Research.

Ventilation needs to be considered with lighting, sound control and solar heat gains. Optimum ventilation maybe to face East or West however, this is an orientation least desirable with regards to solar gains. Discrepancies will occur and research needs to be conducted to decipher which climatic condition is most critical or will use least energy.

Due to the effects of global warming, we may need to reconsider passive cooling techniques now that our climate is changing. With warmer temperatures, more frequent hurricanes, the effectiveness of passive cooling alone may not be as effective as previously. Developing low energy mechanical devices that work in to assist the passive is key; perhaps questioning "*how* can technology assist passive ventilation for cooling?"

This assignment focuses on ventilative cooling, however a lot can be learnt from the vernacular, whether heating or cooling. Architects should take it upon themselves to become familiar with vernacular practices of their region and apply them to a present day context. Australian Architect, Glenn Murcutt, being a fine example.

Word Count

2,728

Appendix

naturally ventilated buildings	criteria	air-conditioned buildings
scattered	urban pattern	dense
open coverage type	building design & construction	closed coverage type
> max.!	ventilation rate	> min.!
> 0!	thermal capacity	> 0!
irrelevant (if shaded)	thermal insulation	necessary
as large as possible	openings	as small as possible
whole building envelope (esp. roof)	shading	whole building envelope (esp. roof)
rain (esp. driving rain) and rising moisture	moisture protection	rain (esp. driving rain) rising moisture and water vapour diffusion

Fig. 10 *Comparisons of main design principles for naturally ventilated buildings and air-conditioned buildings under warm and humid conditions. (Lauber W. 2005 p1057)*

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