


#04

# CIRCADIAN RHYTHM

*A lot of things happen in our body and mind while we sleep.*



# CIRCADIAN RHYTHM

## ■ Circadian rhythm

- Regular biological processes that occur on a 24-hour cycle
- Widely observed in not only humans but also other living things

**Melatonin pg/ml**

Sleepiness -----

**Core body temperature**

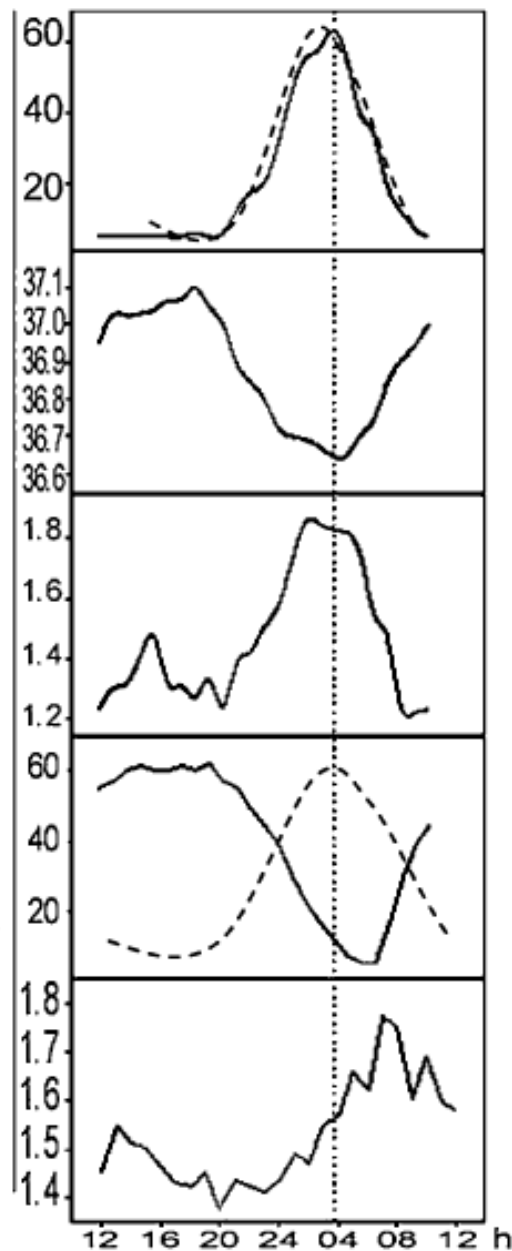
**Triacylglycerol**  
(blood fat)

**Alertness**

Road accidents -----

**Reaction time**

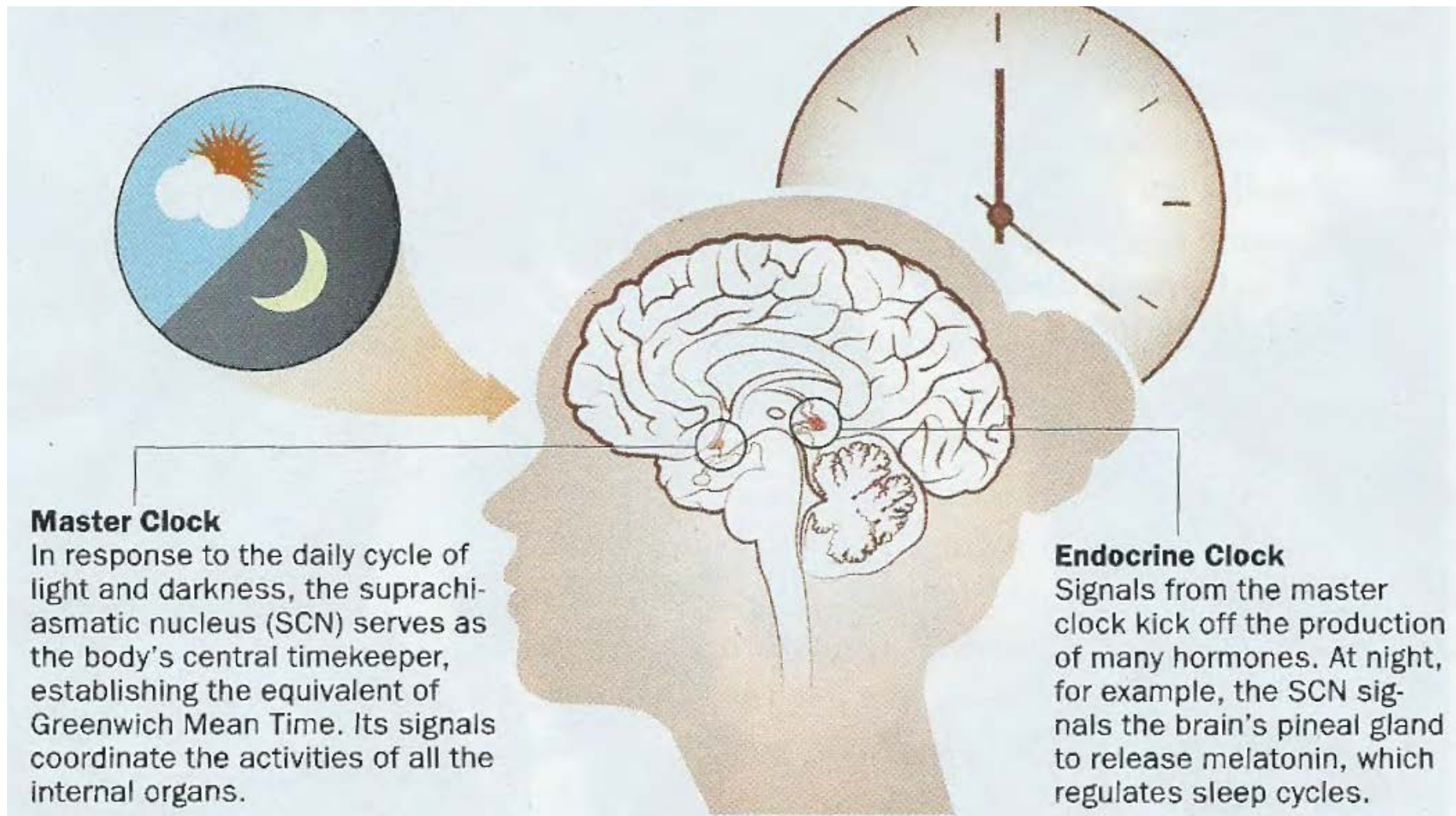
**Clock time h**



← Used as an index of  
body clock time  
(plasma, saliva,  
urine)

**Circadian rhythms  
adapt slowly to a  
change in sleep/work  
schedule**

Examples of circadian rhythm (Arendt, 2010)



The **biological clock**, or master clock, is controlled by the suprachiasmatic nucleus in the hypothalamus, and coordinates the rhythmic activities of other body parts (Laber-Warren, 2015).



### Cardiovascular Clock

To give the heart a rest, blood pressure decreases at night. Most heart attacks occur in the morning, likely because of the rapid increase in blood pressure that accompanies waking.

### Metabolic Clock

Body temperature is high during the day, a state that is metabolically demanding but enables rapid reactions to high-pressure situations such as encountering a predator (or in today's world, a demanding boss). Body temperature drops at night to lower caloric demands.

### Reproductive Clock

Circadian genes help to coordinate the secretion of hormones that regulate ovulation and the menstrual cycle.

### Immune Clock

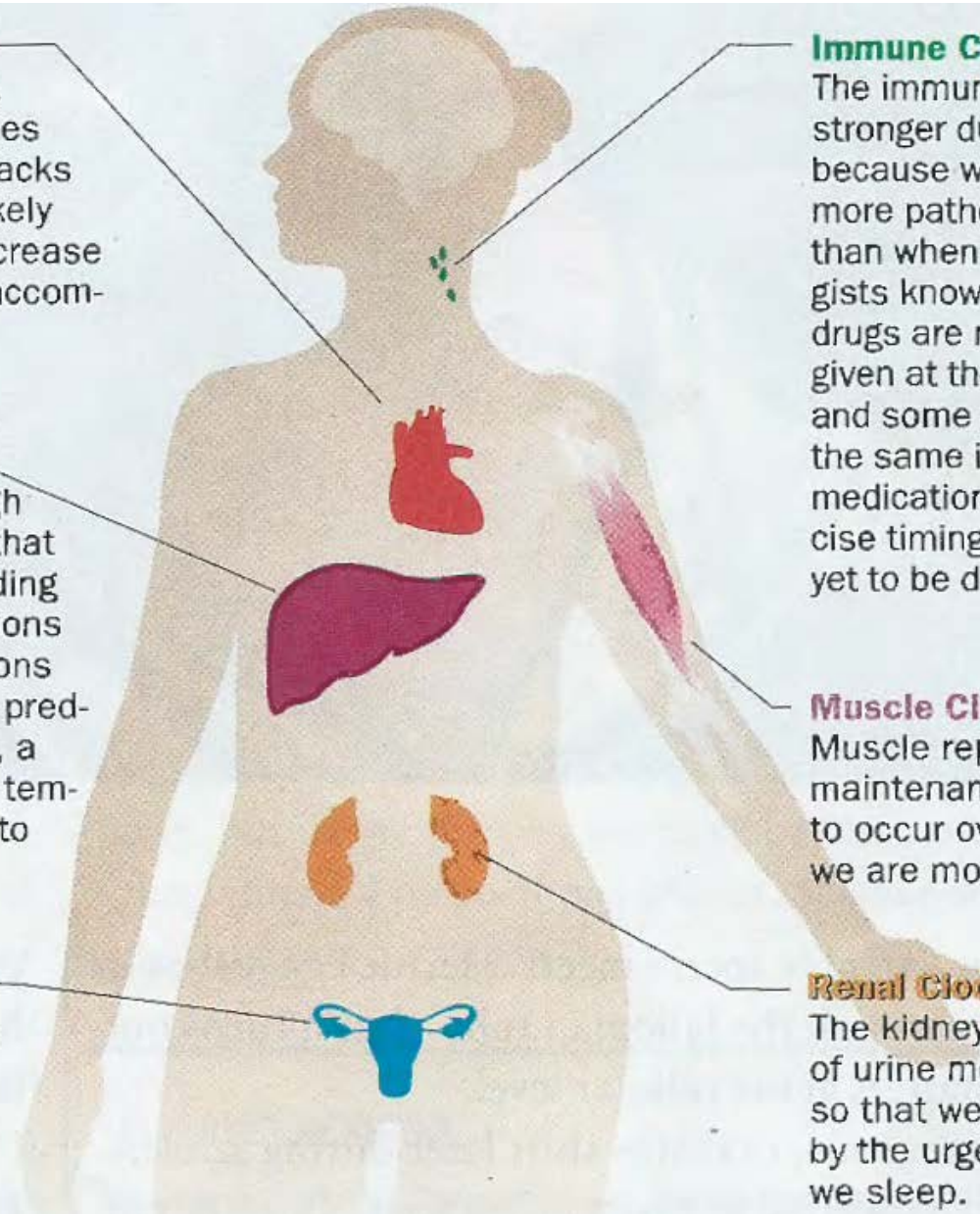
The immune response is stronger during the day, likely because we are exposed to more pathogens while active than when asleep. Oncologists know that some cancer drugs are more effective if given at the right time of day, and some scientists believe the same is true for other medications, although precise timing protocols have yet to be discovered.

### Muscle Clock

Muscle repair and maintenance seem primed to occur overnight, when we are moving less.

### Renal Clock

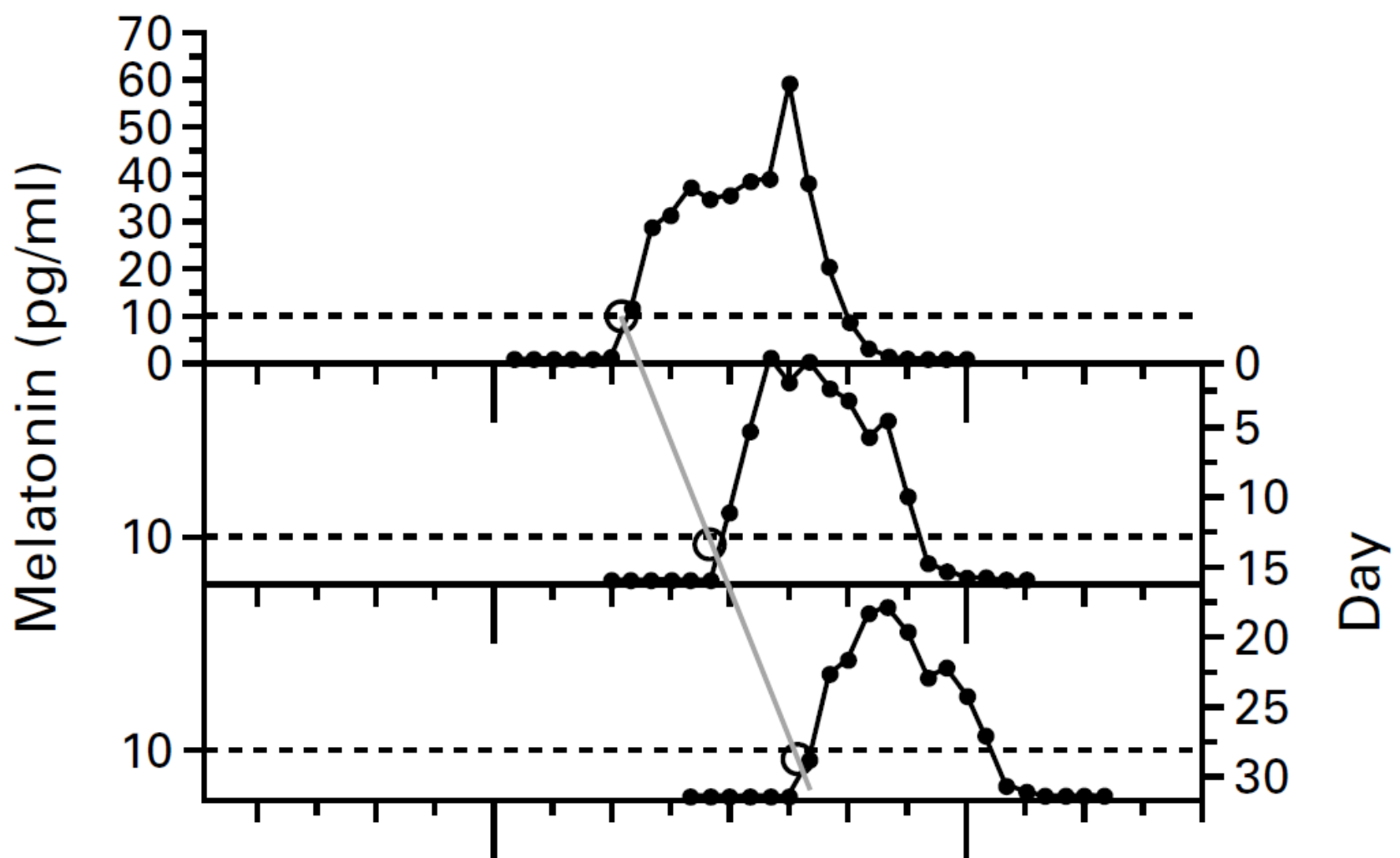
The kidneys filter salt out of urine more slowly at night so that we are not bothered by the urge to urinate while we sleep.



Just about every tissue, gland, and organ in our body follows a circadian rhythm (Laber-Warren, 2015).

## ■ Circadian rhythm

- Without time cues, the circadian rhythm free runs, with a cycle of a few minutes more than 24 hours
- External **zeitgebers** such as light, eating, and activities synchronize or entrain the rhythm to the 24-hour day



The timing of melatonin onset is shown as open circles on the dashed lines. A slanting line indicates a free-running. This blind person showed a free-running rhythm (circadian period = 24.3 hours) (Sack et al., 2000). Submarine sailors show a similar pattern (Kelly et la., 1999).



## ■ Circadian misalignment

- misalignment between the circadian pacemaker and behavioral/environmental cycles
- sleep/wake, eating, light/darkness exposure, or other activities inappropriately timed relative to the biological clock

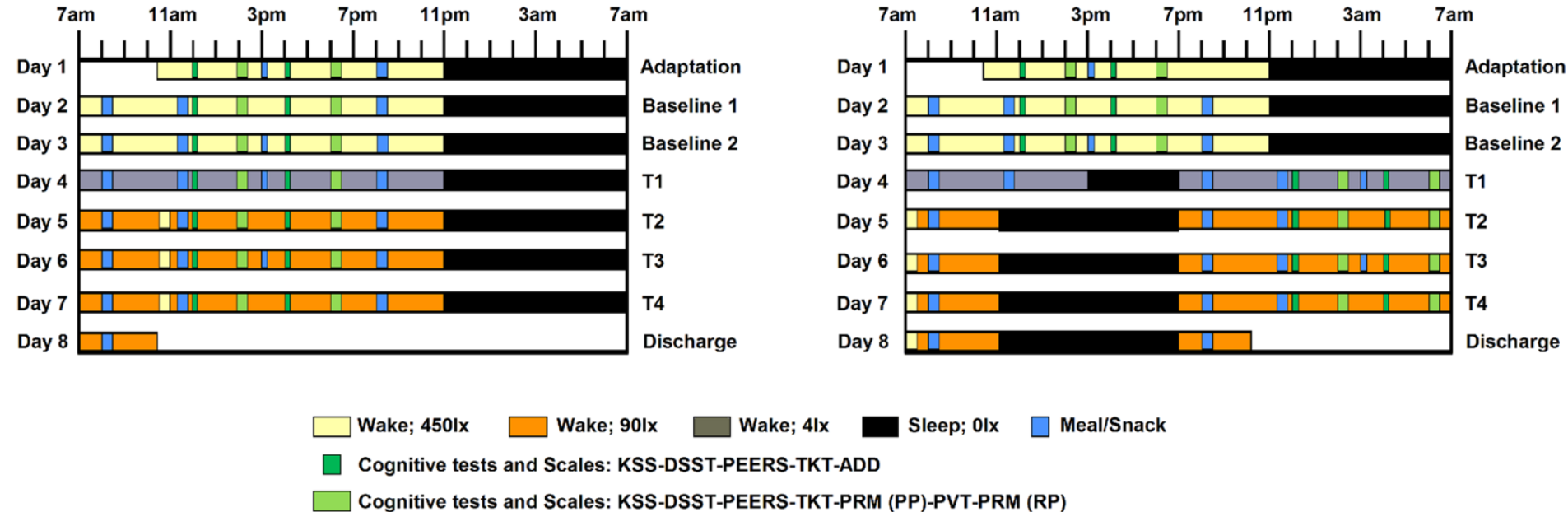
## ■ Circadian misalignment

- Personal: preference and lifestyle; circadian rhythm sleep disorders
- Environmental: daylight saving time; high latitude; social jet lag; shift work; time zone travel
- Modern challenges: staying up late, all-nighters, late night snacks, irregular meal time, lighting, digital devices, 24-hour stores, global connectedness

- Circadian misalignment
  - Associated with insomnia, decreased sleep efficiency and quality, changes in dietary behavior, appetite, glucose regulation, and mood
  - Increases risk for cardiovascular diseases diabetes, obesity and psychiatric conditions

## Circadian Alignment

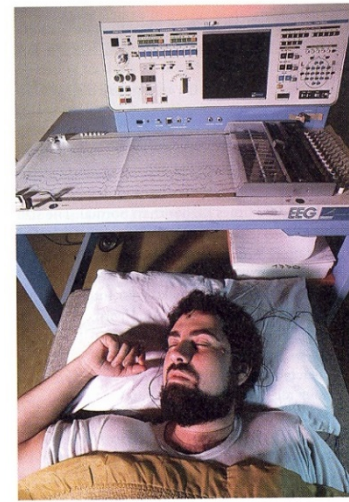
## Circadian Misalignment



A within-subject, randomized experiment, with circadian alignment and misalignment conditions. For the former, scheduled sleep times were from 11pm to 7am across all days, while for the latter, these were inverted by 12 hours after Baseline 2 (Day 3) (Chellappa et al. 2018).

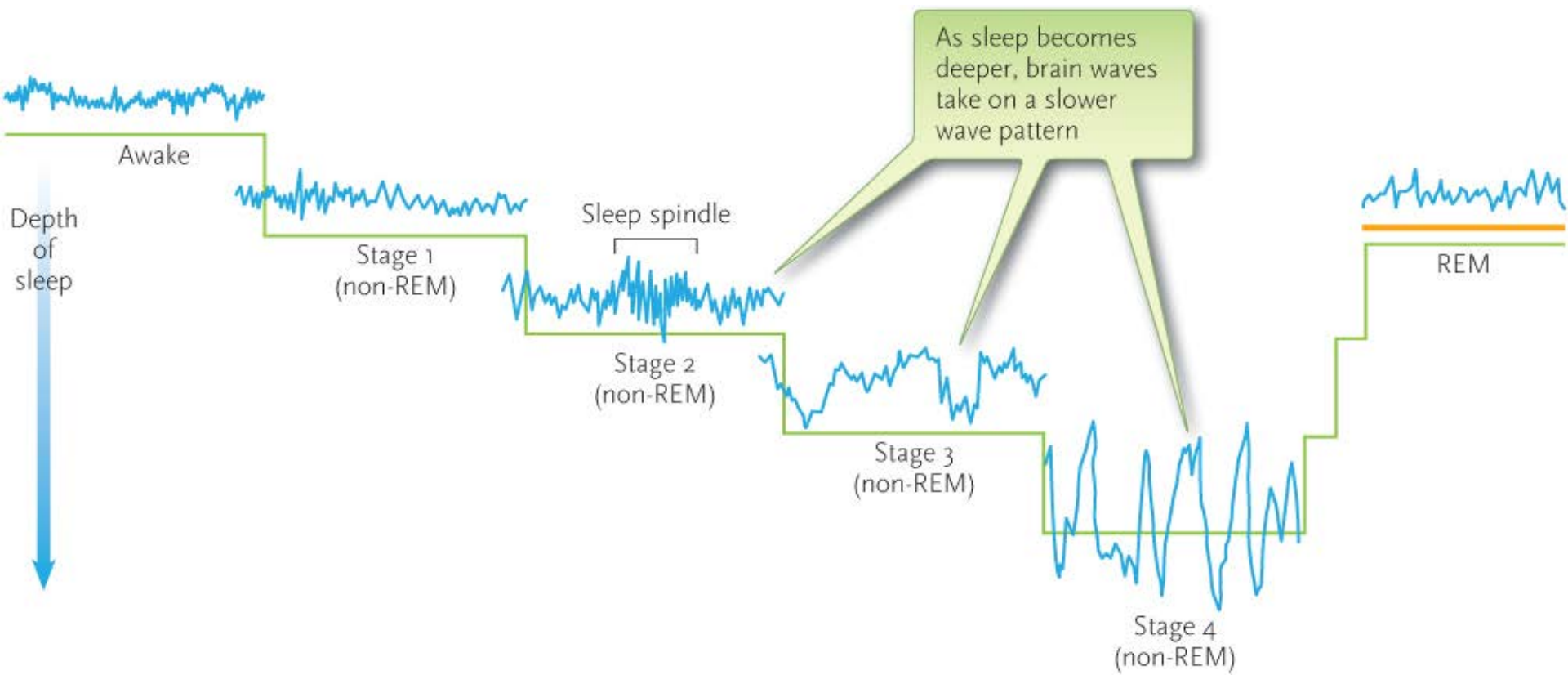
SLEEP



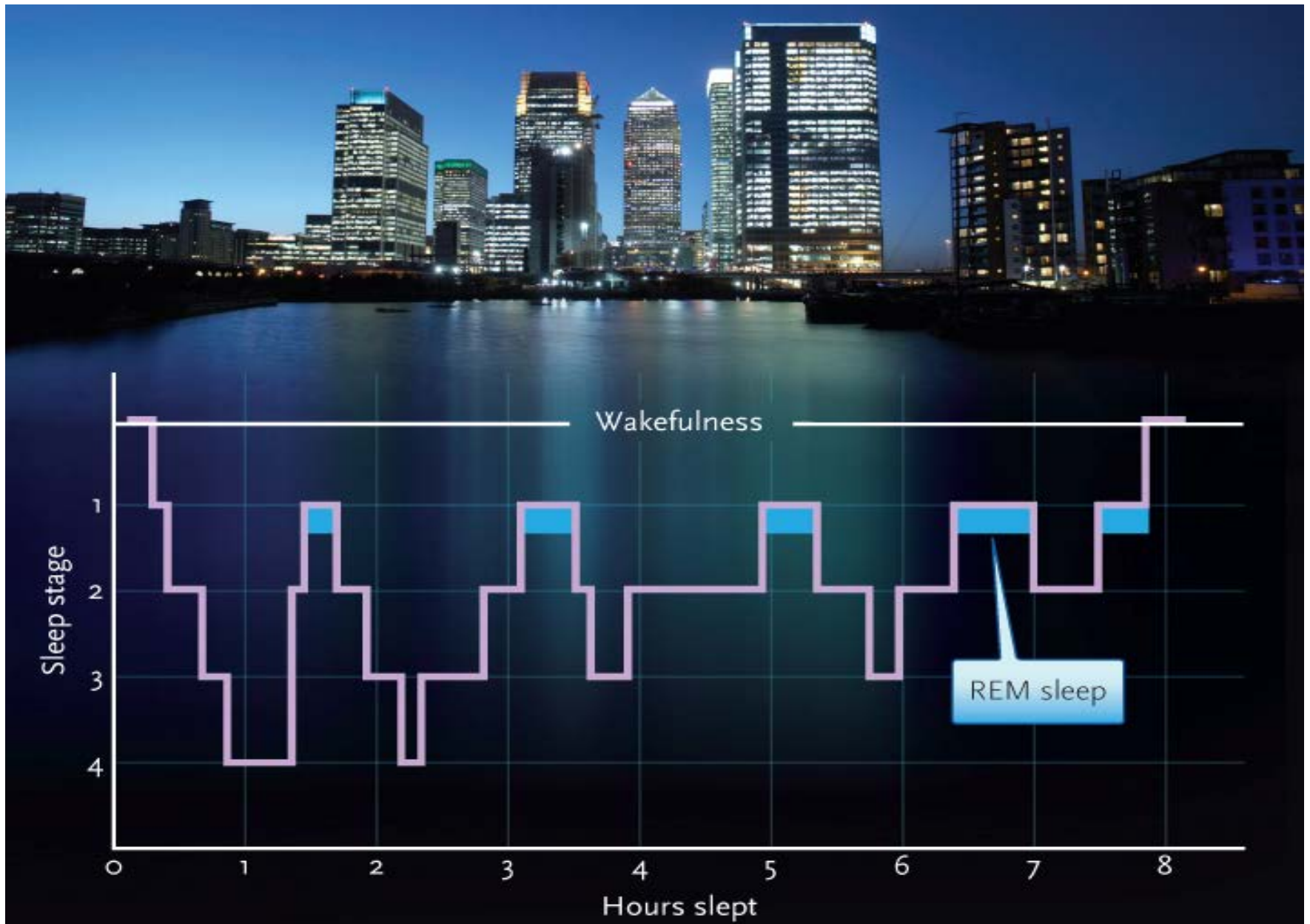


## ■ Sleep cycle

- People cycle through a series of 5 stages during sleep (4 stages of non-rapid eye movement sleep, and one stage of rapid eye movement sleep)
- EEG (brain waves), EMG (muscular activity and tension), and EOG (eyes movement)



Brain-wave patterns vary significantly during the different stages of sleep.



During a sleep, the typical sleeper passes through all four stages and several REM periods

## Non-REM stages

- |       |  |
|-------|--|
| 1     | <ul style="list-style-type: none"><li>• If awakened, people recall some visual images</li><li>• Reduced breathing rate, heart rate, muscle tension, and body temperature</li></ul> |
| 2     | <ul style="list-style-type: none"><li>• Sleep through familiar stimuli, but responsive to unexpected stimuli</li><li>• Further reduced heart rate and muscle tension</li></ul>     |
| 3 & 4 | <ul style="list-style-type: none"><li>• “Deep sleep”, least responsive to outside stimulation</li><li>• Further reduced heart rate and muscle tension</li></ul>                    |

## REM sleep

- Brain waves very similar to those associated with normal wakefulness
- Heart rate, blood pressure, and breathing rate increase, but muscles paralyze
- About 20% of an adult's sleep time
- Rebound effect when deprived
- Wherein most dreams occur



## ■ Restoration hypothesis

- Sleep, particularly Stages 3 and 4, plays an important role for repairing the body
- Vast majority of growth hormone occurs during Stages 3 and 4 (Savine et al., 2000)

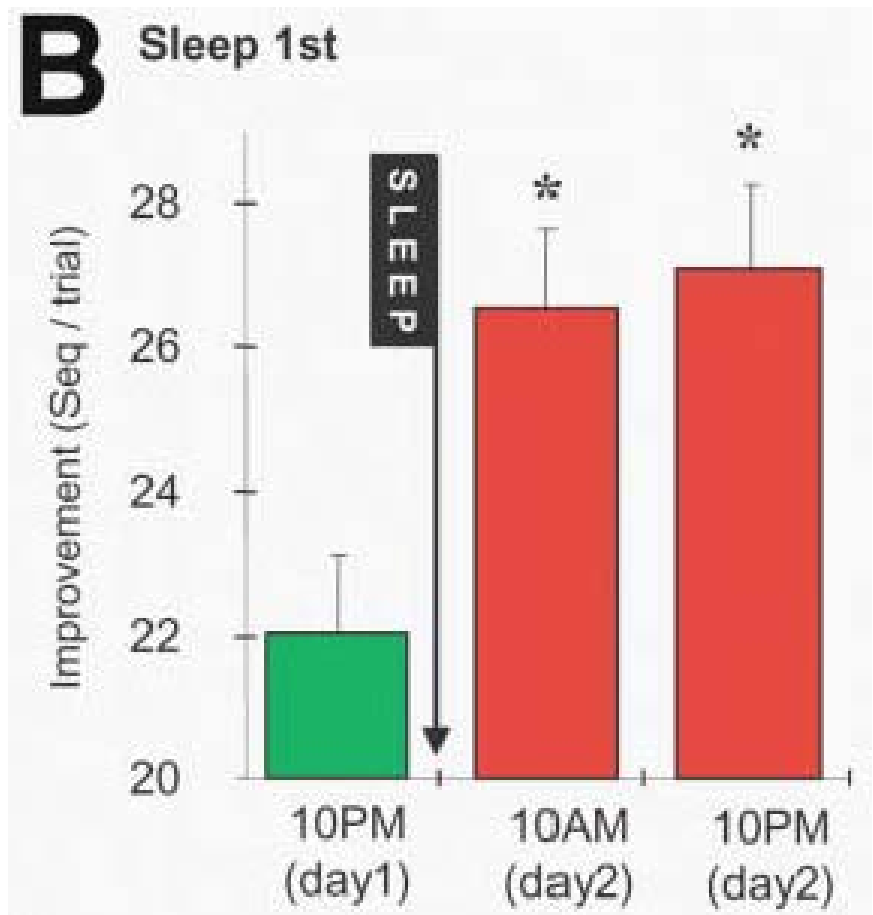
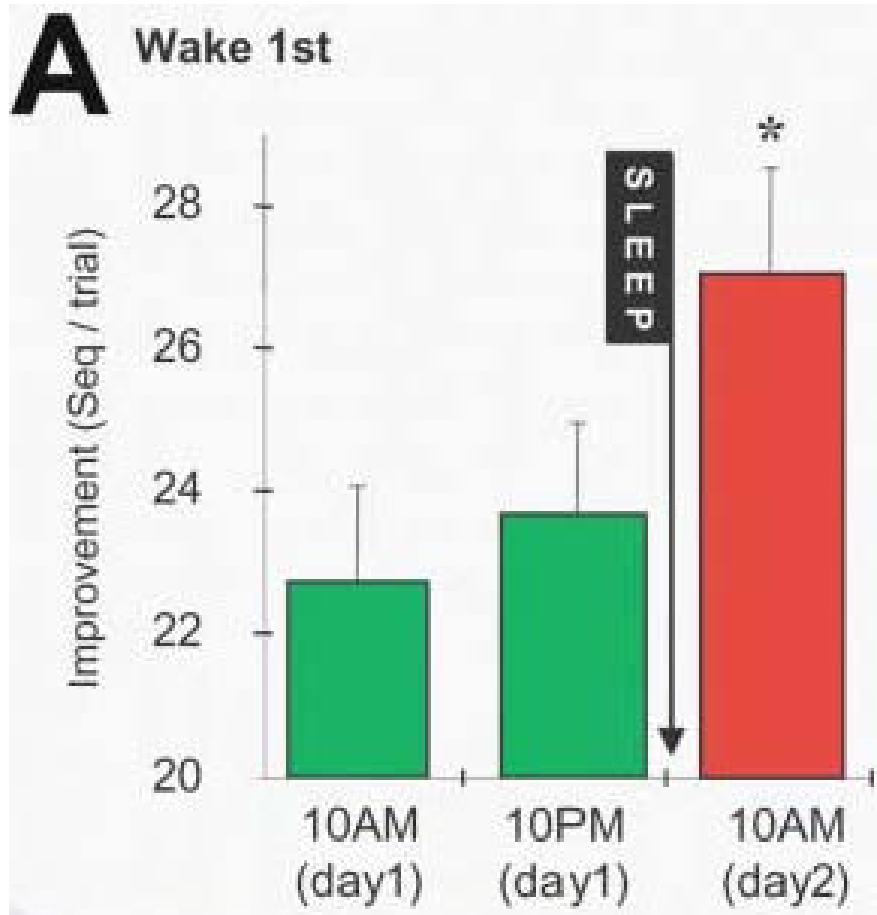
- Restoration hypothesis
  - Sleep deprivation slows healing, impairs immune activity, and reduces production of new neurons in animals (e.g., Murphy et al, 2007)
  - Sleep is associated with better post-exercise recovering and performance among athletes (Samuels, 2008)

## ■ Restoration hypothesis

- Poor sleep and sleep disturbances are associated with various health risks, including obesity, diabetes, heart disease and hypertension, inhibited immune functioning, mood disorders, and lower life expectancy (Cappuccio et al., 2010, 2011)

## ■ Memory consolidation

- Sleep allows our brain to synthesize new experience and existing knowledge, resulting in memory consolidation (Stickgold, 2015)



Participants learned a finger-tapping sequence. Wake 1<sup>st</sup> subjects trained at 10 AM showed no significant change in performance at retest but showed significant improvement following a night of sleep. Sleep 1<sup>st</sup> subjects showed significant improvements at retest following a night of sleep and showed no further improvement after an additional 12 hours wake (Walker et al., 2002).

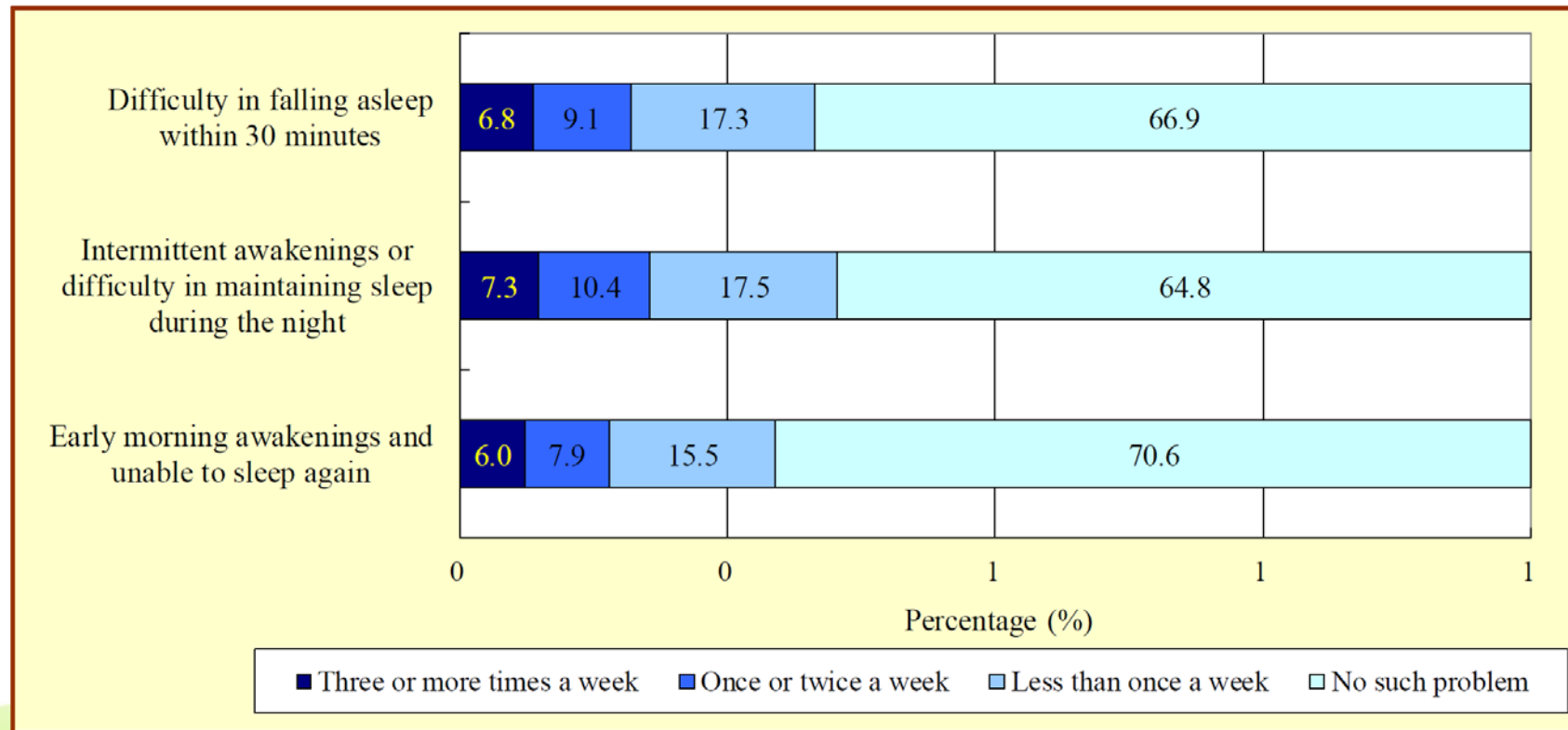


- Sleep disturbances

- Insomnia

- Difficulty in initiating (onset insomnia) or maintaining asleep (maintenance insomnia)
    - Stress, anxiety, substance use (especially stimulants), psychological disorders, or situations

**Figure 3: Frequency of sleep disturbances in the 30 days preceding the survey among non-institutionalised persons aged 15 and above**



Base: All respondents.

Note : Figures may not add up to the total due to rounding.

Source: Population Health Survey 2014/15, Department of Health.

- Sleep disturbances
  - Sleep apnea
    - Difficulty breathing while sleeping, leading to abrupt awakenings for air
    - Central or upper-airway/obstructive (airway blockages)

- Sleep disturbances
  - Narcolepsy (“sleep attack”)
    - Uncontrollable intrusion of REM sleep for short periods during wakefulness
    - Appears to be genetically determined (e.g., narcolepsy runs in families)