To sleep, perchance to dream: why do we and other animals sleep?
Sleep is a universal imperative for all animal species

'Almost all other animals are observed to partake of sleep, aquatic, winged, and terrestrial creatures alike.

Aristotle (384-322 BC) On Sleep and Waking
On average we spend 25 years of our lives asleep!
Is this really necessary?

Our current 24/7 culture denigrates the value of sleep.

'Marxists get up early in the morning to further their cause. We must get up even earlier.'
Margaret Thatcher

'It's the worry that gets you, not the loss of sleep.'
Dale Carnegie
Our current 24/7 culture denigrates the value of sleep.

'...I hate sleeping. It wastes time.'

Isaac Asimov

'Sleep is an acquired habit... a man doesn't need any sleep.'

Thomas Edison
'Early to bed, and early to rise, makes a man healthy, wealthy and ... socially dead!

Animaniacs
Is this really necessary?

Sleep scarcely rates a mention in modern literature

'Sleep that knits up the ravelled sleeve of care......chief nourisher in life's feast'

William Shakespeare (Macbeth)
Is this really necessary?

Are sleep and dreaming really useless vestiges of a past without electricity and light bulbs?
Is this really necessary?

Are sleep and dreaming really useless vestiges of a past without electricity and light bulbs?

If not, what potential impact is our persistent effort to do without it having on us?
Stages of the sleep cycle

Awake and alert
EEG - beta waves (13-30Hz), desynchronised

Sensory awareness
100%

Body temperature
Normal

EEG
EMG
EOG
HR
Stages of the sleep cycle

Lying down to sleep (10-20 minutes)
EEG - alpha waves (8-13Hz), desynchronised

Sensory awareness

EEG
EMG
EOG
HR

Body temperature

75%
Stages of the sleep cycle

Stage 1 (10 seconds to 10 minutes)
EEG - theta waves (3-7Hz) more synchronised
Very close to waking

- EEG
- EMG
- EOG
- HR

Sensory awareness

50%

Body temperature
Stages of the sleep cycle

Stage 2 (10-20 minutes)
EEG - theta waves + K-complexes and spindles

Sensory awareness

EEG
EMG
EOG
HR

Body temperature

50%
Stages of the sleep cycle

Stage 3 (20-30 minutes)
EEG - theta and delta (3Hz) waves

Sensory awareness

50%

Body temperature

HR

EEG

EMG

EOG
Stages of the sleep cycle

Stage 4 (30-40 minutes)
EEG - delta waves

EEG
EMG
EOG
HR

Sensory awareness

50%

Body temperature
Stages of the sleep cycle

Back through stage 3....

EEG

EMG

EOG

HR

Sensory awareness

50%

Body temperature
Stages of the sleep cycle

Back through stage 3....
and stage 2 over 10 minutes or so

EEG

EMG

EOG

HR

Sensory awareness

50%

Body temperature
Stages of the sleep cycle

Stage 5 REM (10 minutes)
EEG - beta waves (as when awake and alert)

Sensory awareness

50%

Body temperature

HR

EOG

EMG

EEG
Stage 5 REM (10 minutes)
EEG - beta waves (as when awake and alert)

Rapid eye movements

Muscle paralysis - except for heart, respiration and eyes

Penile and nipple erections, clitoral engorgement and vaginal lubrication

If woken from this stage dreams reported 80 - 90% of time
Two hours a day paralysed with physical signs of sexual arousal!
Do we only dream during REM sleep?

No, we dream in all stages of sleep.

Dreams are instantly forgettable.
So what do we dream about?

REM dreams are vivid, emotional and often fantastical

The majority are nightmares
So what do we dream about?

Non-REM dreams are more realistic and mundane
So what do we dream about?

Dream experiences occur in real time
So what do we dream about?

Dream experiences occur in real time

Based in the present and involve the dreamer
So what do we dream about?

Sex differences:

Men dream about men more than women do!
So what do we dream about?

Sex differences:

Men dream about men more than women do!

Having a partner makes dreams more forgettable.
So what do we dream about?

Do dreams provide:

Novel discoveries? X
So what do we dream about?

Do dreams provide:

Novel discoveries? X

Visions of the future? X
So what do we dream about?

Do dreams provide:

Novel discoveries? X

Visions of the future? X

Telepathic communication? X
So what do we dream about?

Do dreams provide:

- Novel discoveries? ❌
- Visions of the future? ❌
- Telepathic communication? ❌
- Divine communication? ?
So what do we dream about?

Do dreams provide:

Novel discoveries? X

Visions of the future? X

Telepathic communication? X

Divine communication? ?

Jazzed up action replays? ✓
Playing back memories
Are our dreams filled with sex?

We show signs of sexual arousal for 2 hours of dreaming each night!
Are our dreams filled with sex?

We show signs of sexual arousal for 2 hours of dreaming each night!

Freud and the unconscious

If awake men think of sex every six seconds do they dream about it as well?
Are our dreams filled with sex?

We show signs of sexual arousal for 2 hours of dreaming each night!

- Freud and the unconscious
- If awake men think of sex every six seconds do they dream about it as well?
- No - dream content does not cause erections
Are our dreams filled with sex?

Dream reports
- is sex really a nightmare?

Erections often still occur in impotence

Alcohol abuse and ageing have little effect

Even babies show these changes

Severe brain damage often has no effect
So what makes us physically aroused?

Sleep scientist: 'I have no idea where dreams come from but the erect penis might serve as the antenna for receiving them!'

Waking up for sex rather than a cup of tea?
So what makes us physically aroused?

Sleep scientist: 'I have no idea where dreams come from but the erect penis might serve as the antenna for receiving them!'

Waking up for sex rather than a cup of tea?

Genital workout?
So what makes us physically aroused?

Vascular or neuromuscular changes during REM paralysis?
Lucid dreams

These are REM dreams where you have some control

Generally very pleasant and are often about sex!
....something put my last nights dream into my head, which I think was the best that ever was dreamed - which was that I had my Lady Castlemayne in my arms and was admitted to use all the dalliance I desired with her, and then dreamed that this could not be awake but was only a dream.'

Samuel Pepys  15th August 1665
Problem: lucid dreams are rare
Lucid dreams

Problem: lucid dreams are rare

If you overdo the control or emotional side you wake up!
Lucid dreams

Answer: practice can improve things

Think about what you want in your dreams during the day

Make a habit of remembering all your dreams each day
Are we viewing our dreams during REM sleep?

Not unless we all dream of Wimbledon!
Are we viewing our dreams during REM sleep?

Not unless we all dream of Wimbledon!

Stirring up the aqueous humour in the eye.
So how much do other animals sleep?

Medium sleepers

Human  8.0h
Pig    7.8h
So how much do other animals sleep?

Short sleepers - typically grazing animals living in the open

<table>
<thead>
<tr>
<th>Animal</th>
<th>Sleep Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horse</td>
<td>1.9h</td>
</tr>
<tr>
<td>Giraffe</td>
<td>2.9h</td>
</tr>
<tr>
<td>Sheep</td>
<td>3.8h</td>
</tr>
<tr>
<td>Cow</td>
<td>3.9h</td>
</tr>
<tr>
<td>African Elephant</td>
<td>3.3h</td>
</tr>
</tbody>
</table>
So how much do other animals sleep?

Long sleepers - typically small burrow/cave dwellers

<table>
<thead>
<tr>
<th>Animal</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Star-nosed mole</td>
<td>10.3h</td>
</tr>
<tr>
<td>Mouse</td>
<td>12.1h</td>
</tr>
<tr>
<td>Rat</td>
<td>12.5h</td>
</tr>
<tr>
<td>Squirrel</td>
<td>14.9h</td>
</tr>
<tr>
<td>Opossum</td>
<td>16.0h</td>
</tr>
<tr>
<td>Brown bat</td>
<td>19.9h</td>
</tr>
</tbody>
</table>
So how much do other animals sleep?

**Predators** -

<table>
<thead>
<tr>
<th>Animal</th>
<th>Sleep Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolf/dog</td>
<td>10.6h</td>
</tr>
<tr>
<td>Jaguar</td>
<td>10.8h</td>
</tr>
<tr>
<td>Cheetah</td>
<td>12.1h</td>
</tr>
<tr>
<td>Cat</td>
<td>12.1h</td>
</tr>
<tr>
<td>Lion</td>
<td>13.5h</td>
</tr>
<tr>
<td>Tiger</td>
<td>15.8h</td>
</tr>
</tbody>
</table>
So how much do other animals sleep?

Other primates -

<table>
<thead>
<tr>
<th>Animal</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimpanzee</td>
<td>9.7h</td>
</tr>
<tr>
<td>Squirrel monkey</td>
<td>9.9h</td>
</tr>
<tr>
<td>Baboon</td>
<td>10.3h</td>
</tr>
<tr>
<td>Rhesus monkey</td>
<td>11.8h</td>
</tr>
<tr>
<td>Owl monkey</td>
<td>17.0h</td>
</tr>
</tbody>
</table>
So how much do other animals sleep?

Champion sleeper: two-toed sloth - 20 hours

The three-toed sloth only sleeps 14.4 hours

So is it all about toes?
Proportion of time in REM sleep (2 - 60%)

<table>
<thead>
<tr>
<th>Species</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platypus</td>
<td>57.1</td>
</tr>
<tr>
<td>Ferret</td>
<td>41.4</td>
</tr>
<tr>
<td>Opposum</td>
<td>41.3</td>
</tr>
<tr>
<td>Human</td>
<td>25.0</td>
</tr>
<tr>
<td>Cat</td>
<td>15.0</td>
</tr>
<tr>
<td>Dog</td>
<td>10.3</td>
</tr>
<tr>
<td>Giraffe</td>
<td>10.3</td>
</tr>
<tr>
<td>Dolphin</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Other species also get erections at this time.

It's not only human men who fall asleep afterwards.
Sleep duration

This is dictated by lifestyle, predation risk and size
Sleep duration

This is dictated by lifestyle, predation risk and size

What about the proportion of REM sleep?
This is dictated by lifestyle, predation risk and size

What about the proportion of REM sleep?
This is dictated by lifestyle, predation risk and size.

What about the proportion of REM sleep?

Could we be more like a sheep or a platypus than a pig after 1000 years?
Sleeping with one eye open

What about birds, dolphins and whales?

Answer: Uni-hemispheric sleep
Sleeping with one eye open

What about birds, dolphins and whales?

Answer: Uni-hemispheric sleep

Must have very little REM sleep (usually 1% or less)
Sleeping with one eye open

Visual system is completely crossed
Sleeping with one eye open

What about humans?

Problems:
Sleeping with one eye open

What about humans?

Problems:

Each eye communicates with both sides of the brain
Sleeping with one eye open

What about humans?

Problems:

Each eye communicates with both sides of the brain

Language and face recognition are localised on different sides
Sleeping with one eye open

What about humans?

Answer:

We could use glasses with half-obscured lenses but:
Sleeping with one eye open

What about humans?

Answer:

We could use glasses with half-obscured lenses but:

For half of the day we could not use language!

For the other half we could not recognise anyone!
Sleeping position is important

Humans have to be horizontal to sleep properly

MOST POPULAR SLEEPING POSITIONS

- Foetus 41%
- Log 15%
- Yearner 13%
- Soldier 8%
- Freefaller 7%
- Starfish 5%
Sleeping position is important

Humans have to be horizontal to sleep properly
Sleeping position is important

Humans have to be horizontal to sleep properly

So travel 1st class on long-haul journeys
Sleeping position is important

So travel 1\textsuperscript{st} class on long-haul journeys or hope that Richard Branson performs an economy-class miracle!
So travel 1st class on long-haul journeys or hope that Richard Branson performs an economy-class miracle!
Do other animals dream?
Do other animals dream?

Animals often move and vocalise during sleep.
Do other animals dream?

Animals often move and vocalise during sleep.

Experimental proof is seen when brain control over REM paralysis is removed.
Do other animals dream?

Animals often move and vocalise during sleep

Experimental proof is seen when brain control over REM paralysis is removed

Imagine our own world if humans were not paralysed during REM sleep.......
'Jack sleepwalks to a urinal that doesn't exist.....

...and recovers nicely by blaming the whole thing on the dog!'

from 'Snapshots by' Jason Love
What regulates sleep?

Brainstem centres that regulate arousal

Biological clocks - melatonin
What regulates sleep?

Brain arousal transmitters

Serotonin
- Neocortex
- Thalamus
- Basal ganglia
- Amygdala
- Hypothalamus
- Substantia nigra
- Raphe nuclei

Dopamine
- Neocortex
- Thalamus
- Basal ganglia
- Amygdala
- Hypothalamus
- Substantia nigra
- Ventral tegmentum

Norepinephrine
- Neocortex
- Thalamus
- Basal ganglia
- Amygdala
- Hypothalamus
- Locus coeruleus

Uppers
- Alcohol
- Amphetamine (speed)
- Modafinil (Provigil)
- Ritalin
- Ecstasy
What regulates sleep?

Brain arousal transmitters

- Serotonin
  - Raphe nuclei
  - Substantia nigra
  - Hypothalamus
  - Amygdala

- Dopamine
  - Substantia nigra
  - Ventral tegmentum
  - Nucleus accumbens

- Norepinephrine
  - Locus coeruleus

Downers
- Alcohol
- Ketamine
- Haloperidol
What regulates sleep?

Brain arousal transmitters

Brain inhibitory transmitters

Barbiturates

Benzodiazepines

Cocaine

Caffeine
What regulates sleep?

Brain arousal transmitters
Brain inhibitory transmitters
REM sleep and acetylcholine
What wakes us up?

Your ACTH internal alarm clock

Waking up with a start but ready!
What wakes us up?

External alarm clock only - wake up feeling like a zombie

'So how often do you wake up grumpy?'

'Not often - she gets up when she wants'
What wakes us up?

Orexin/hypocretin
What wakes us up?

Orexin/hypocretin

Orexin levels tend to be high during REM sleep

Kiyashchenko et al. J. Neuroscience 2002
What wakes us up?

Orexin/hypocretin

Orexin levels tend to be high during REM sleep

The 24h waking drug?
(Modafinil)
Can we and other animals survive without sleep?

NO!
Can we and other animals survive without sleep?

NO!

2-3 weeks of sleep deprivation will kill you.

Sleep is more important for survival than food.
Can we and other animals survive without sleep?

Prior to death:

- debilitated appearance
- skin lesions
- increased food intake
- weight loss

- increased metabolic rate
- reduced body temperature
- reduced immune defences

Death is caused mainly by infection through bacteria, viruses and parasites.
The perils of sleep deprivation

World record for staying awake

1965
Randy Gardner (11 days, 12 minutes)

2000
Maureen Weston (18 days 17 hours)

1988
Robert McDonald (18 days 21.6 hours)
The perils of sleep deprivation

Both acute and chronic sleep deprivation can affect all body functions:

- attention
- motor co-ordination
- learning and memory
- emotional and psychological state
- sexual drive and fertility
The perils of sleep deprivation

Both acute and chronic sleep deprivation can affect all body functions:

- attention
- motor co-ordination
- learning and memory
- emotional and psychological state
- sexual drive and fertility
- appetite
- growth
- metabolic rate
- immunocompetence
- life expectancy...

It can also shrink the size of your brain!
The perils of sleep deprivation

Sleep deprivation is a popular torture used by the Indonesian Secret Police....
The perils of sleep deprivation

Sleep deprivation is a popular torture used by the Indonesian Secret Police....

...and small babies!
The perils of sleep deprivation

Quick fixes:

Play catch-up at the weekend

Try a 15-minute afternoon nap
Driving under the influence of sleep deprivation
Driving under the influence of sleep deprivation

Sleep deprivation may be as big a killer on our roads as excess alcohol!

Causes 30% of crashes on New York Thruway

Causes 20% (~23,000) of all crashes in the UK
Driving under the influence of sleep deprivation

29% of all UK drivers admitted to nearly falling asleep while driving at least once during the last 12 months.
Driving under the influence of sleep deprivation

29% of all UK drivers admitted to nearly falling asleep while driving at least once during the last 12 months

Attention and reaction times

Reaction time

- Normal
- 36 hours without sleep
- 5 pints of beer
Driving under the influence of sleep deprivation

Driving under the influence of lack of sleep is not generally considered a crime
Sleep helps boost your immune defences

Sleep deprivation is usually accompanied by a high incidence of minor illnesses
Growth, repair and immune function

In animals 7 hours of sleep deprivation blocked effects of flu immunisation

![Bar graph showing antibody levels for control and immunised groups with and without sleep deprivation.](image)

Brown et al 1989
Growth, repair and immune function

In humans the same effect is seen

Sleep deprived
4 hours per night for 6 days

Control

Immunisation
+ 10 days

Spiegel et al JAMA 2002
Growth, repair and immune function

Many important hormones are secreted during sleep:

Testosterone
Many important hormones are secreted during sleep:

Testosterone

Growth hormone - important for growth, repair and new synapse formation

(peaks in Stage 4 sleep)
Growth, repair and immune function

**Hormones**
Thyroid stimulating hormone
Follicle stimulating hormone
Luteinizing hormone
Growth hormone
Testosterone
Melatonin
Prolactin
Cortisol
ACTH

**Energy metabolism**
Triacyl glycerol
Glucose

**Blood and Immune system**
Blood viscosity
Fibrinolytic activity (goes down)
NK cell activity (killer cells – innate immunity)
Other Lymphocytes (white blood cells – antibodies)
Eosinophils (white blood cells – allergies and infection)
Education and adolescence

Young babies need to sleep up to 16 hours a day

Adolescents still need around 10 hours of sleep
Young babies need to sleep up to 16 hours a day

Adolescents still need around 10 hours of sleep

If they get up at 7.30 am are they asleep by 9.30 pm?
Education and adolescence

Young babies need to sleep up to 16 hours a day

Adolescents still need around 10 hours of sleep

If they get up at 7.30 am are they asleep by 9.30 pm?

Sleeping in at weekends - rebellion, laziness or catch-up?
Does sleep deprivation affect educational attainment?
Does sleep deprivation affect educational attainment?

All GCSE and SATS advisory sites emphasise importance of sleep.

Time to do the paper round?

Teenagers stressed out by exams need plenty of pampering by their parents, says Wendy Berliner.

Tuesday May 20, 2003
The Guardian
Education and adolescence

Does sleep deprivation affect educational attainment?

All GCSE and SATS advisory sites emphasise importance of sleep.

Studies in USA suggest that reduction of sleep by 30-40 minutes significantly reduced success.

Being 'cool' and regularly staying up late might lead to 50 years in a dead end job!
Caffeine and sugar junkies

The human race is awash with caffeine

Photomicrograph of crystalline caffeine
Caffeine and sugar junkies

The human race is awash with caffeine

It is a plant toxin evolved to poison insect parasites
Caffeine and sugar junkies

The human race is awash with caffeine

It is a plant toxin evolved to poison insect parasites

It is present in coffee, tea, soft drinks, chocolate, medicines and even sold in tablet form
Caffeine and sugar junkies

The human race is awash with caffeine

It is a plant toxin evolved to poison insect parasites

It is present in coffee, tea, soft drinks, chocolate, medicines and even sold in tablet form

Coffee contains 60-100mg/cup caffeine......
Caffeine and sugar junkies

...and is the second most traded commodity worldwide
Caffeine and sugar junkies

Humans are only species that consumes this drug (50% of Americans consume more than 300 mg/day)

It has a half-life of 6 - 7 hours

Note: Semi-log plot!
Caffeine and sugar junkies

We excrete so much of it (average blood levels are around 10mg/kg)......that it is used to show the spread of human effluent out into the sea!
Caffeine and sugar junkies

Caffeine is effectively an addictive drug like amphetamines, cocaine and heroin, although much less potent.

It is a strong stimulant, increases our alertness and gives us a buzz.
Caffeine and sugar junkies

Soft-drink manufacturers say it is added to improve taste

Studies do not appear to support this
Caffeine and sugar junkies

Energy drinks
Caffeine and sugar junkies

Caffeine disrupts sleep

“No wonder you have insomnia... lying there awake all night.”
Caffeine and sugar junkies

Caffeine disrupts sleep

Blocks ability of adenosine to act on its receptors
Sleep disorders

35 million Americans have chronic insomnia

65 million Americans have significant sleep disorders

25% of US citizens take drugs to aid sleep
Sleep disorders

In your 50's and 60's you average 46 minutes less sleep than in your 20's

'Chastity is the torment of youth, insomnia of age, and at neither stage does it ever seem possible to get enough of what you want'

A Alvarez
Sleep disorders

Narcolepsy

WHAT IS NARCOLEPSY?

THIS ISN'T....

THIS IS!
Sleep disorders

Narcolepsy

Orexin deficiency caused by auto-immune disorder?
Sleep disorders

Snoring

Relaxation of throat musculature

70 - 90 decibels

Main sufferers are:

Male, overweight and drink too much
Snoring affects examination performance in trainee doctors
Sleep disorders

Snoring - remedies?

Nasal dilator strips
Sleep disorders

Snoring - remedies?

Nasal dilator strips

Unusual workout remedy
Snoring - remedies?

Nasal dilator strips

Unusual workout remedy

- press tongue against teeth for 2 minutes
Snoring - remedies?

Nasal dilator strips

Unusual workout remedy

- press tongue against teeth for 2 minutes
- grasp pencil between teeth for 10 minutes
Sleep disorders

Sleep apnoea

Suffered by 10% of middle-aged men
Sleep disorders

Airways totally blocked for up to 10 seconds

**Normal Breathing**
- Airway is open
- Air flows freely to lungs

**Obstructive Sleep Apnea**
- Airway collapses
- Blocked air flow to lungs
Sleep disorders

Airways totally blocked for up to 10 seconds

Can happen over 100 times per night
Sleep disorders

Difficult to diagnose:
Sleep disorders

Difficult to diagnose:

- heavy snorer
- waking up feeling shattered and depressed
- waking up with splitting headache
Difficult to diagnose:

- heavy snorer
- waking up feeling shattered and depressed
- waking up with splitting headache

(not associated with excessive alcohol)
So why do we sleep and dream?

Saving energy?

Recharging the batteries?

Re-setting the clocks?

Putting out the trash?
So why do we sleep and dream?

Consolidating memories?
So why do we sleep and dream?

Consolidating memories?

Inspiring insight?

Subjects gaining insight (%)

Wake day
Wake night
Sleep

Wagner et al
Nature 2004
A unified explanation?

Why maintain a waking state?
A unified explanation?

Why maintain a waking state?

Metabolic rate
A unified explanation?

Why maintain a waking state?

Metabolic rate

REM sleep
A unified explanation?

Why maintain a waking state?

Metabolic rate

REM sleep - ready to go?
A unified explanation?

Why maintain a waking state?

Metabolic rate

REM sleep - ready to go?

Sensory deprivation
A unified explanation?

Why maintain a waking state?

Metabolic rate

REM sleep - ready to go?

Sensory deprivation

Memory consolidation
Could we evolve to do without sleep?

Yes - probably
Conclusions

Don't miss out on your sleep

Get horizontal when you want to sleep

Try to remember to enjoy your sleep and dreams....

....but don't read too much into them
Try an afternoon nap

Regulate your caffeine, sugar and alcohol intake

Don't miss out on sleep and drive

Don't disturb sleeping teenagers at the weekend!
Conclusions

Sleeping may help solve some of your problems