

The Neuroscience of Prevention

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Give someone a fish, and
you feed them for a day.



Who's to blame?

Individual



Genes



Environment



Drugs



Who's to blame?

stigmatize
alienate
criminalize
incarcerate
treat (best scenario)



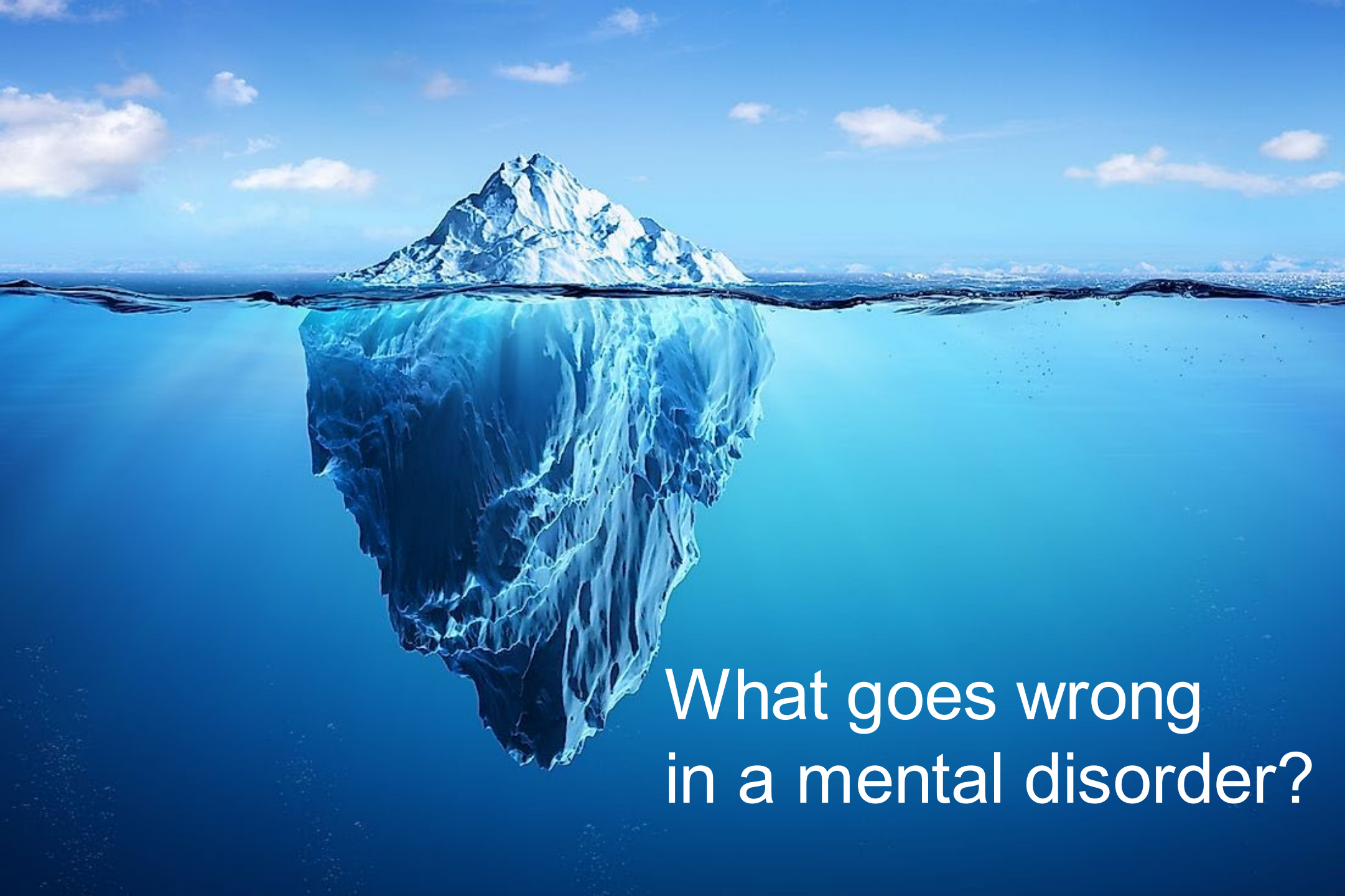


Prevent human
suffering and disease
from happening
in the first place

What went wrong?

- **The human brain**
- **The effect of addictive drugs**
- **Interindividual differences in risk**
- **Boosting resilience**

- **The human brain**
- **The effect of addictive drugs**
- **Interindividual differences in risk**
- **Boosting resilience**



What goes wrong
in a mental disorder?

In the case of addiction

A product failure

The brain is a product



**Upkeep and
Maintenance**
(metabolism)

**Information
Processing**
(cognition)

**Interactions
with the world**
(behavior)

Survival & Reproduction

**Products
Fail:**

Design flaws

Manufacturing errors

Extreme Conditions



**Products
Fail:**

Design flaws

Manufacturing errors

Extreme Conditions





**Three sources of
brain failure**

Evolutionary mismatch

Developmental errors

Overwhelming events



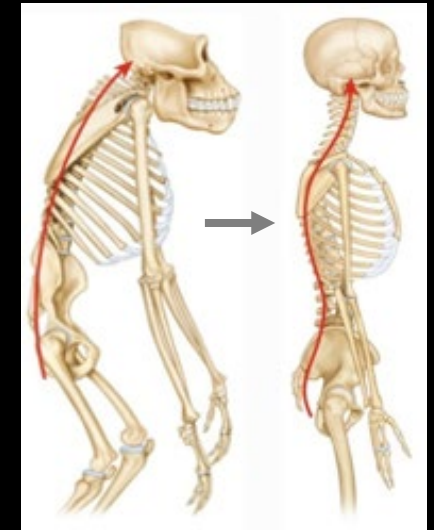
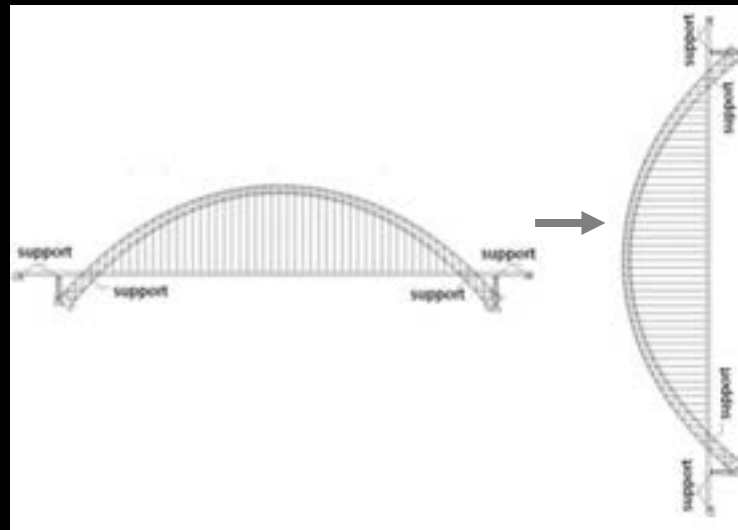
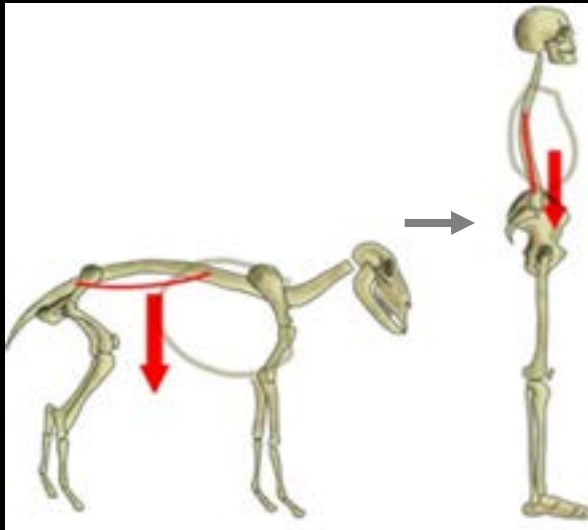
Three sources of brain failure

Evolutionary mismatch

Developmental errors

Overwhelming events

Bipedalism

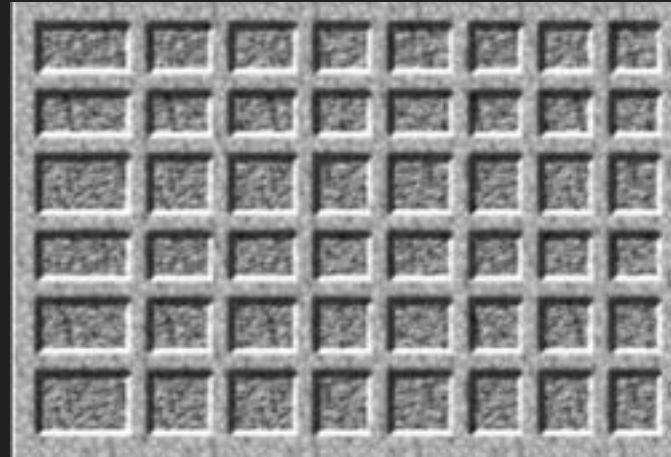
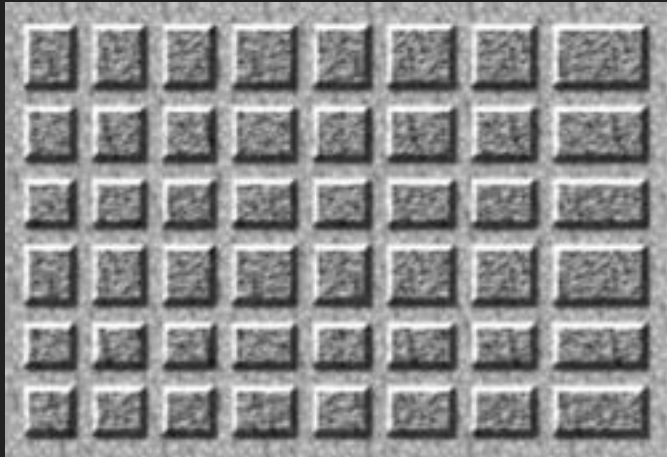


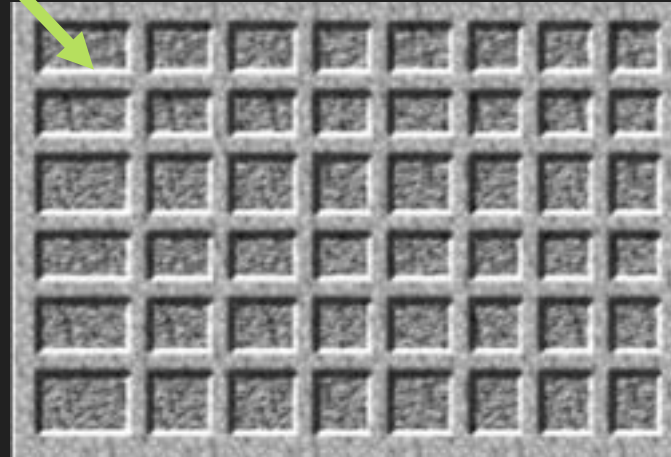
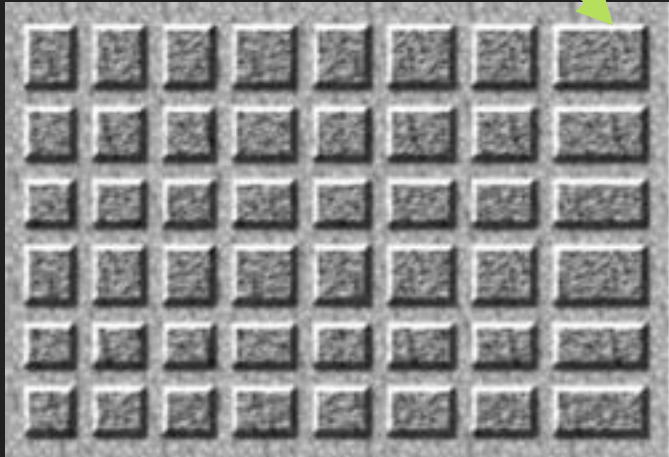
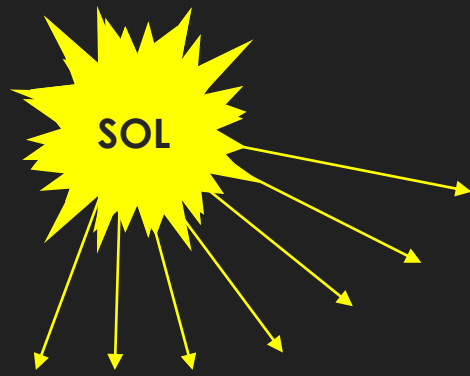
- increased stability
- increased mobility



- compromised anatomy
- predisposition for lower back injuries

Perception of reality





The likelihood of biological damage and failure increases in rapidly changing environments.





environment

biology

Seek the fattiest meat, the sweetest fruits, the most high-energy foods





ORIGINAL GLAZED



STRAWBERRIES & KREME



LEMON MERINGUE PIE



FOOTBALL DOUGHNUT



CARAMEL DREAMCAKE



CHOCOLATE ICED GLAZED

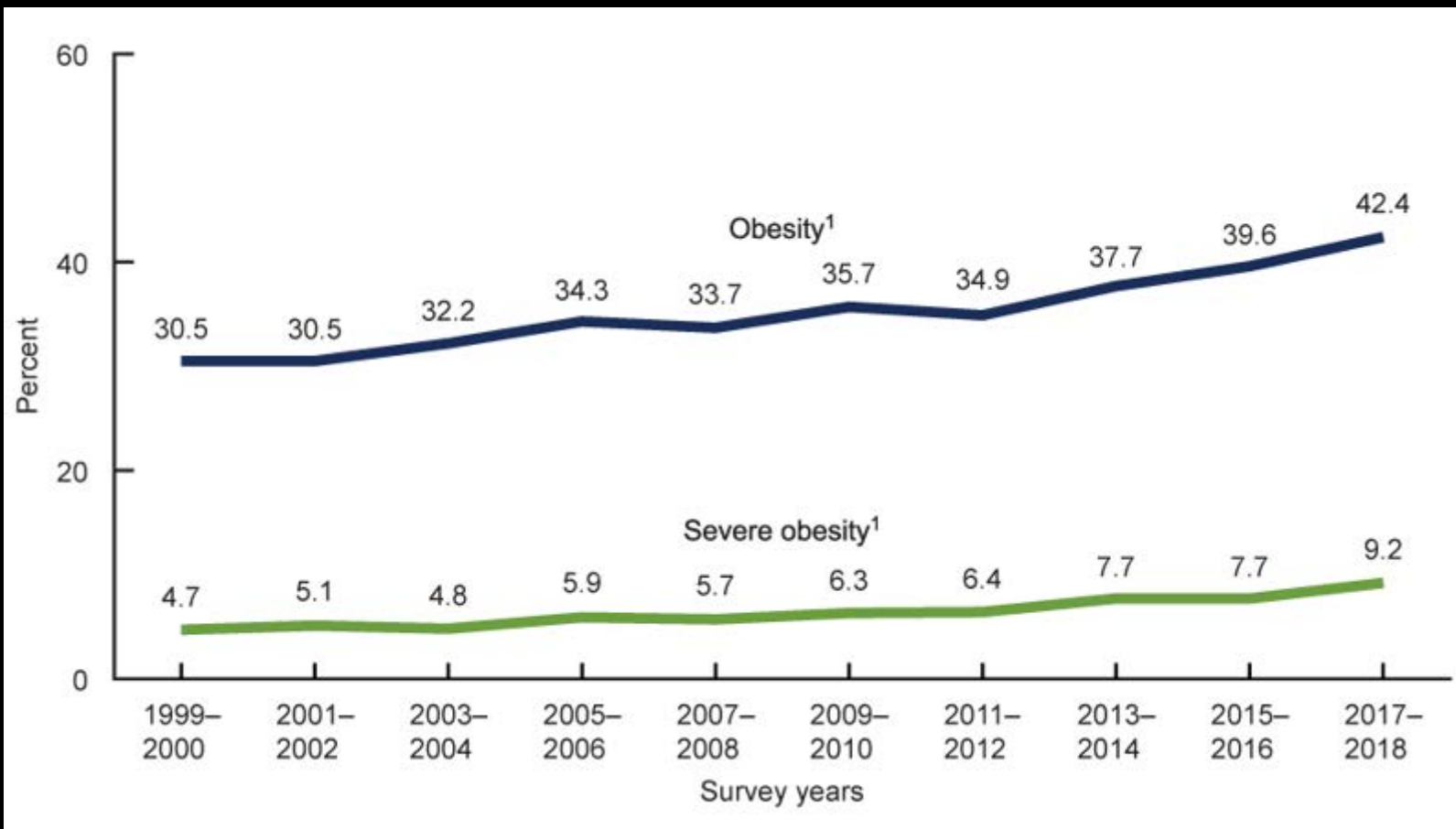


COOKIES & KREME £1.55



GLAZED DOUGHNUT HOLES

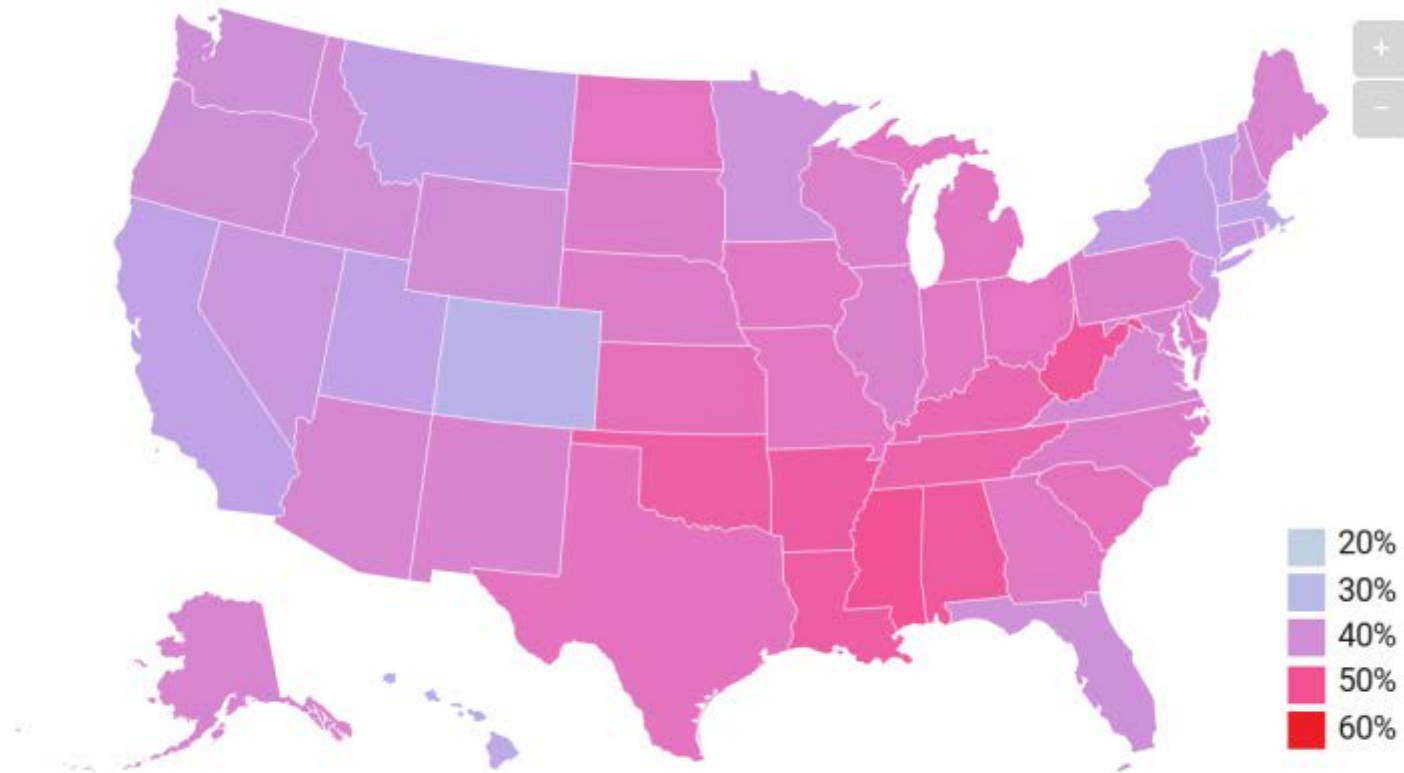




SOURCE: National Center for Health Statistics (CDC)
National Health and Nutrition Examination Survey, 1999-2018.

Half of the U.S. Population Will Be Obese by 2030

Obesity rates by state, 2019



Obesity is defined as a BMI over 30

Map: Elijah Wolfson for TIME • Source: N Engl J Med 2019;381:2440-50. • Created with Datawrapper



**ULTRA
PROCESSED
FOODS (UPF)**

Adverse health outcomes linked to UPF exposure

Among adults

- Overweight, obesity and cardio-metabolic risks;
- Cancer;
- Type-2 diabetes;
- Cardiovascular diseases;
- Irritable bowel syndrome;
- Depression;
- All-cause mortality.

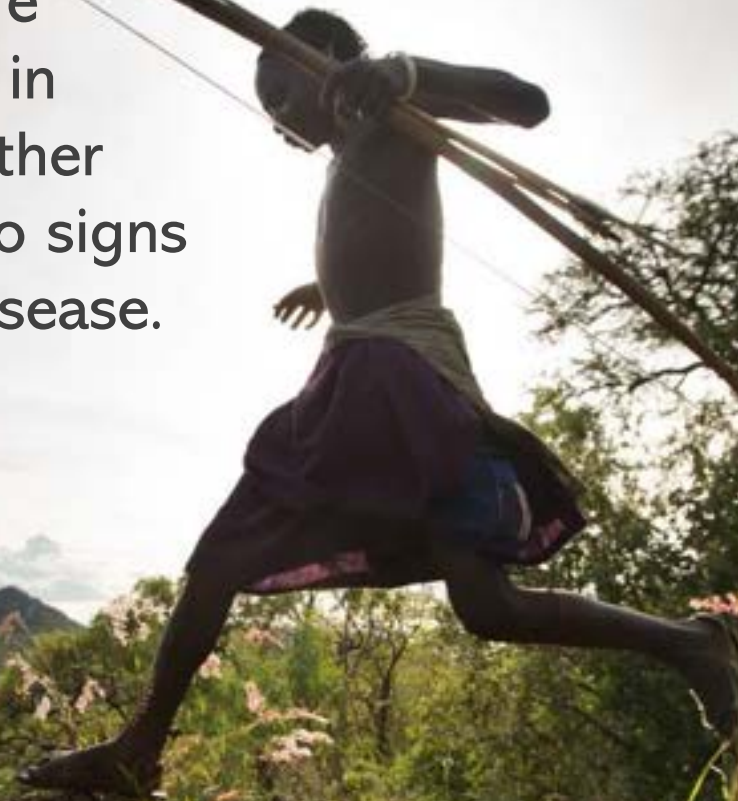
Among children and adolescents

- Cardio-metabolic risks;
- Asthma
- Poorer locomotor skills children ages 3 to 5
- Lower cardiovascular fitness 12- to 15-year-olds

Vernarelli et al. UPFs Intake Is Associated With Poor Cardiovascular Fitness in US Children and Adolescent (2022)

Elizabeth et al. Ultra-Processed Foods and Health Outcomes: A Narrative Review. *Nutrients* 12(7): 1-33 (2020)

The Hadza of Northern Tanzania are moving much of the time, typically in moderate and sustained activity rather than vigorous bursts. They show no signs of risk factors for cardiovascular disease.



Heart Association





The transition to modernity and disease

Obesity
UPF exposure
Lack of exercise
Excessive SM
Addiction

“Diseases of Mismatch”

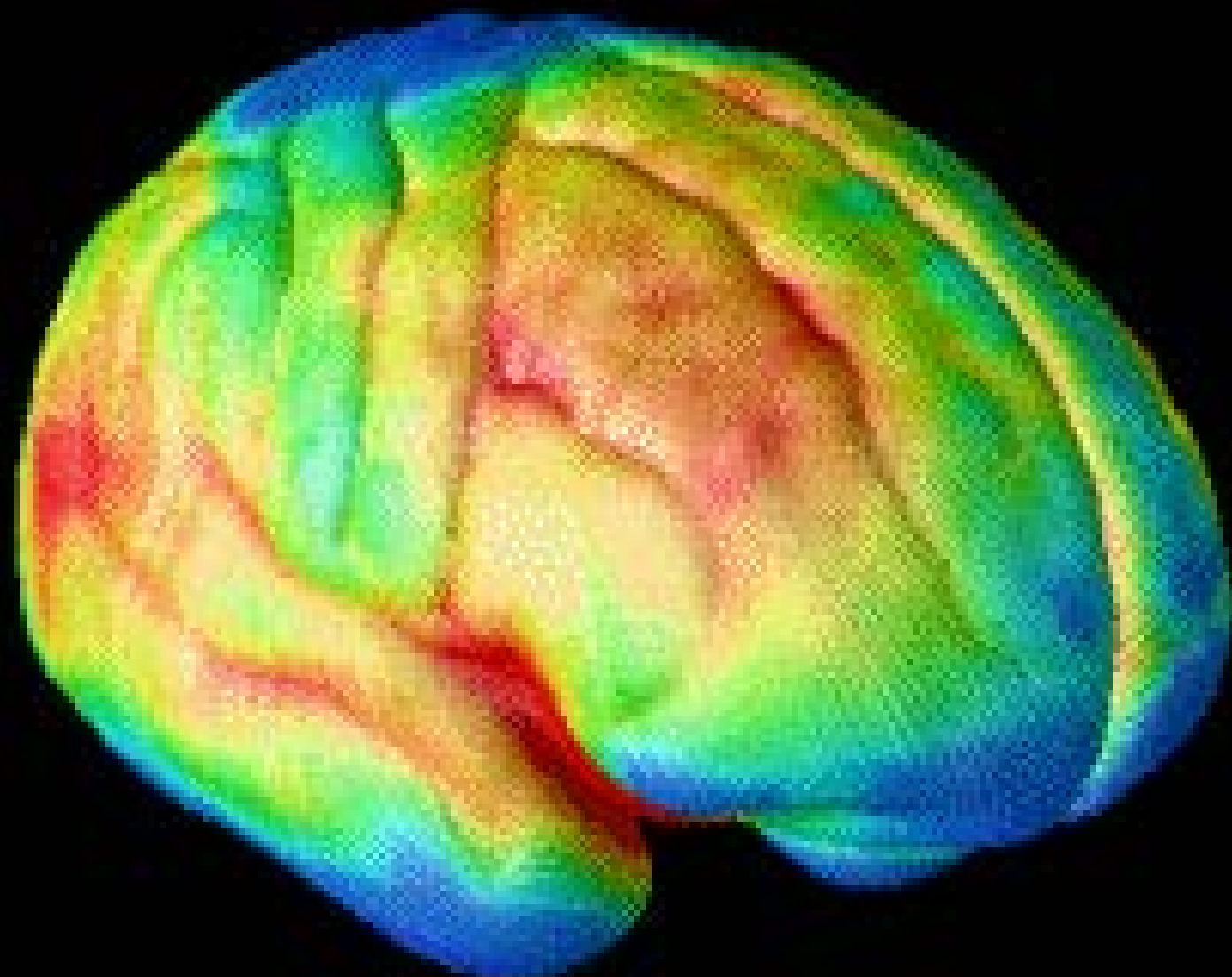


**Three sources
of brain failure**

Evolutionary mismatch

Developmental errors

Overwhelming events



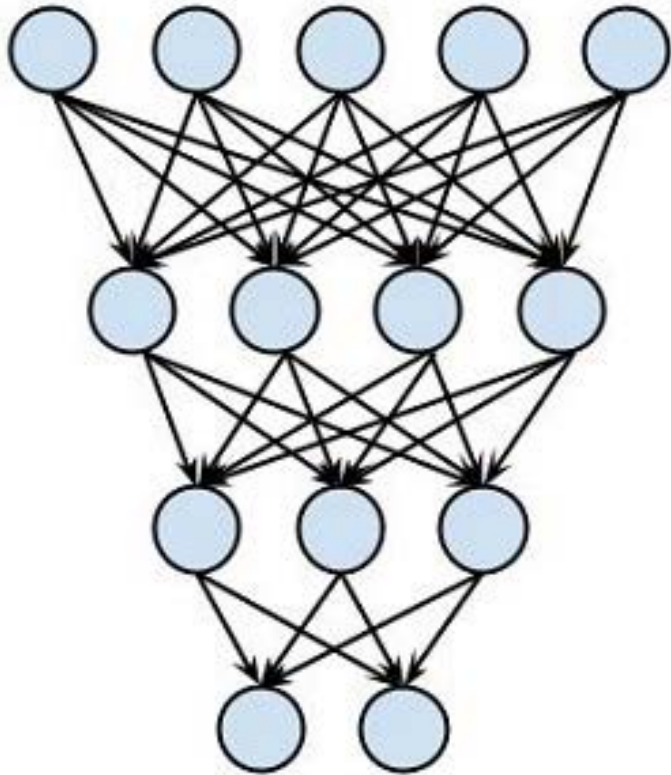
What is Brain Development?



“Programming” a young brain (?)

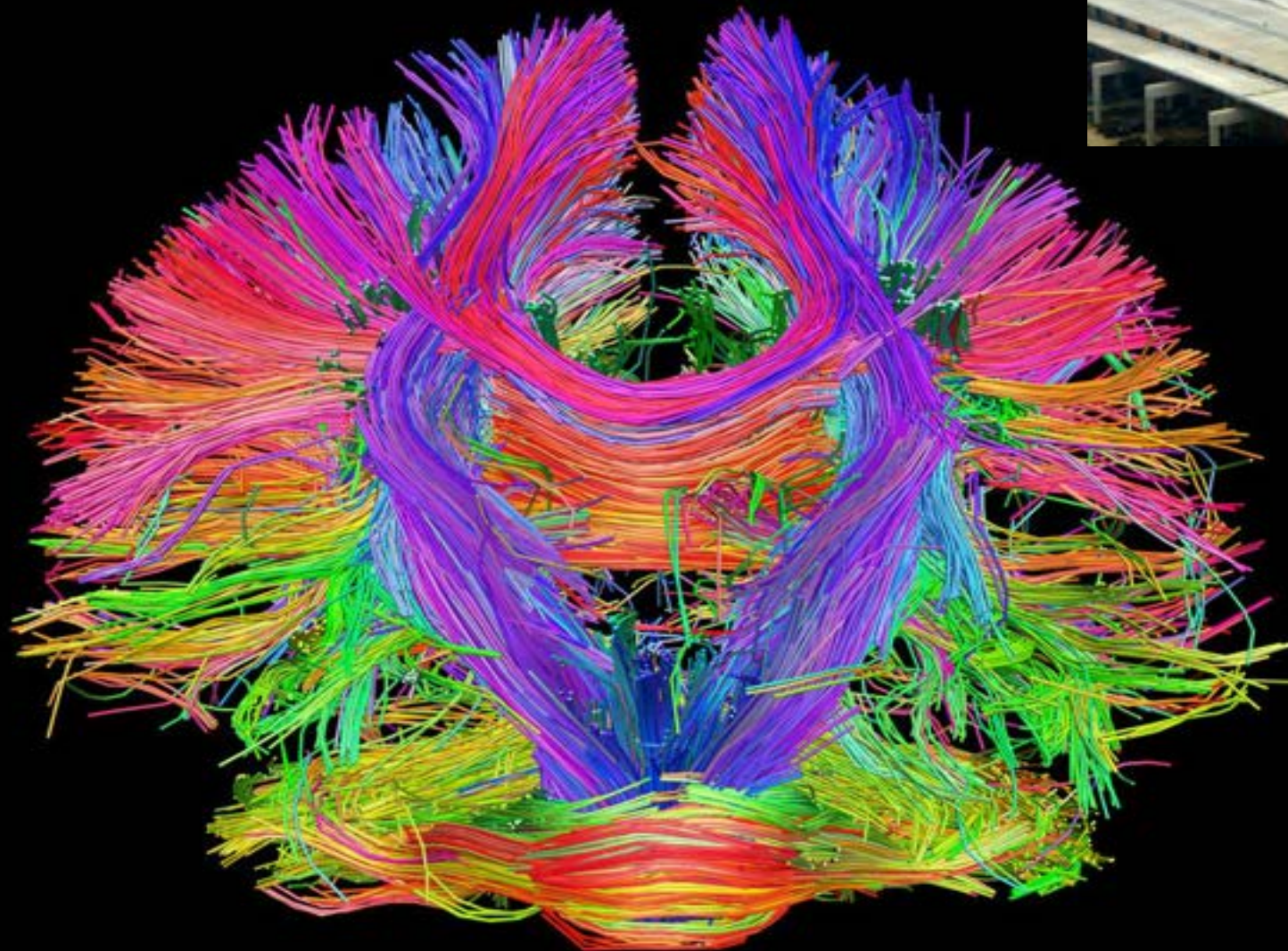


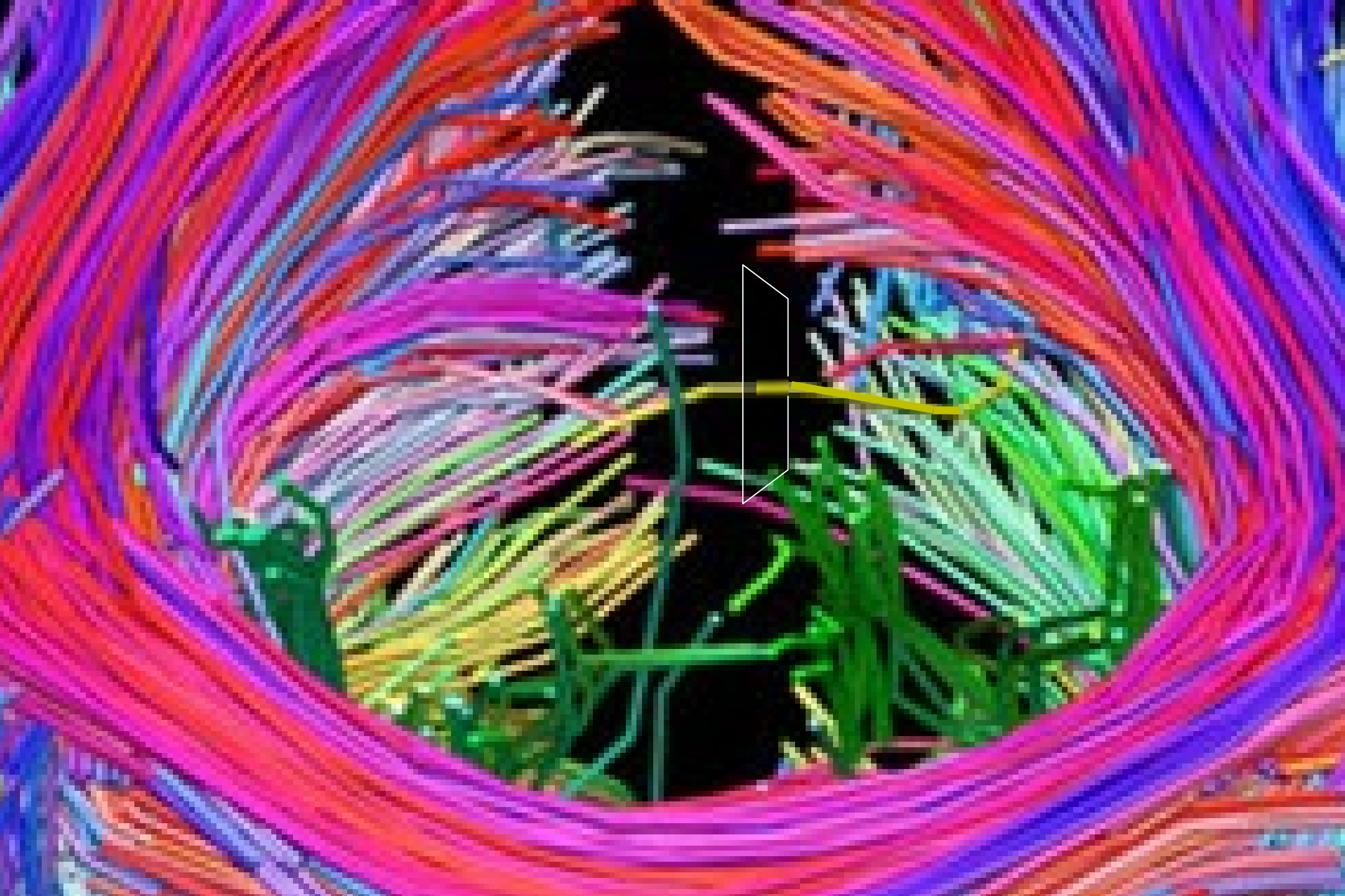
before pruning

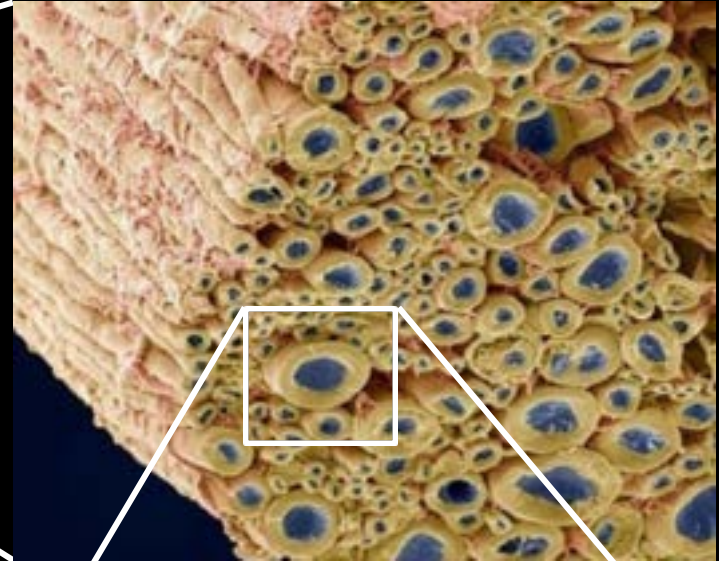
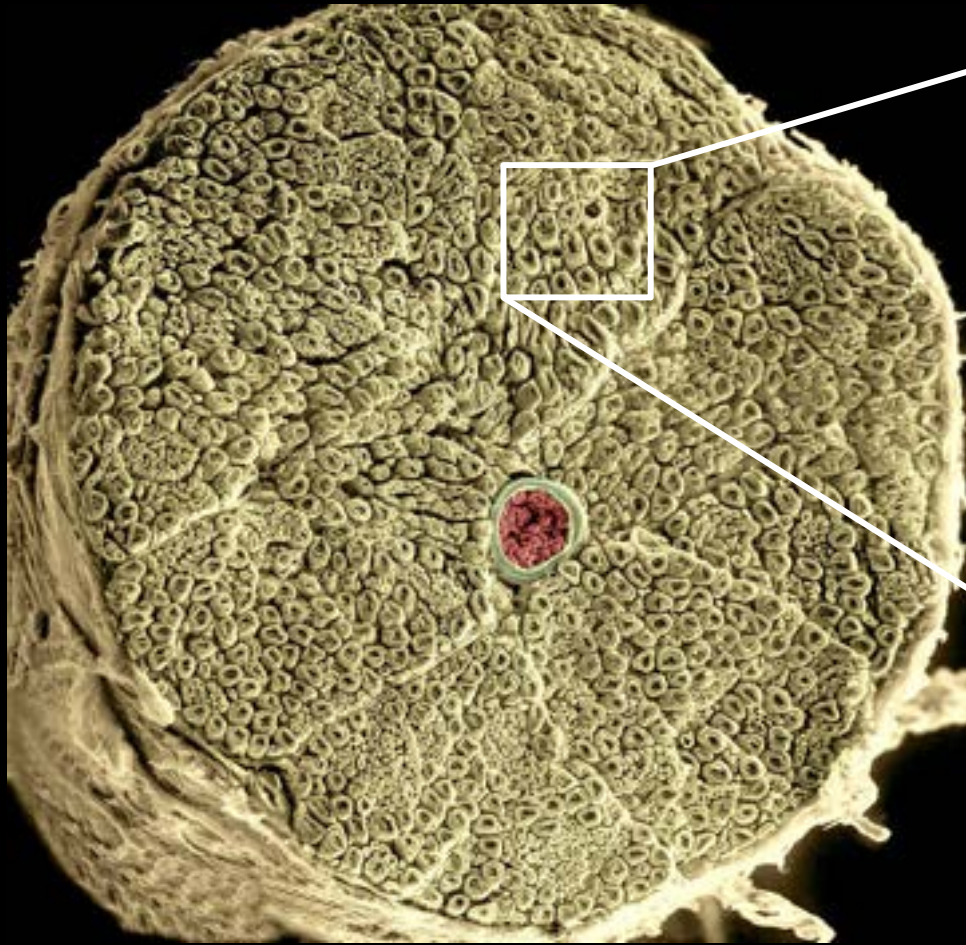




Information Highways



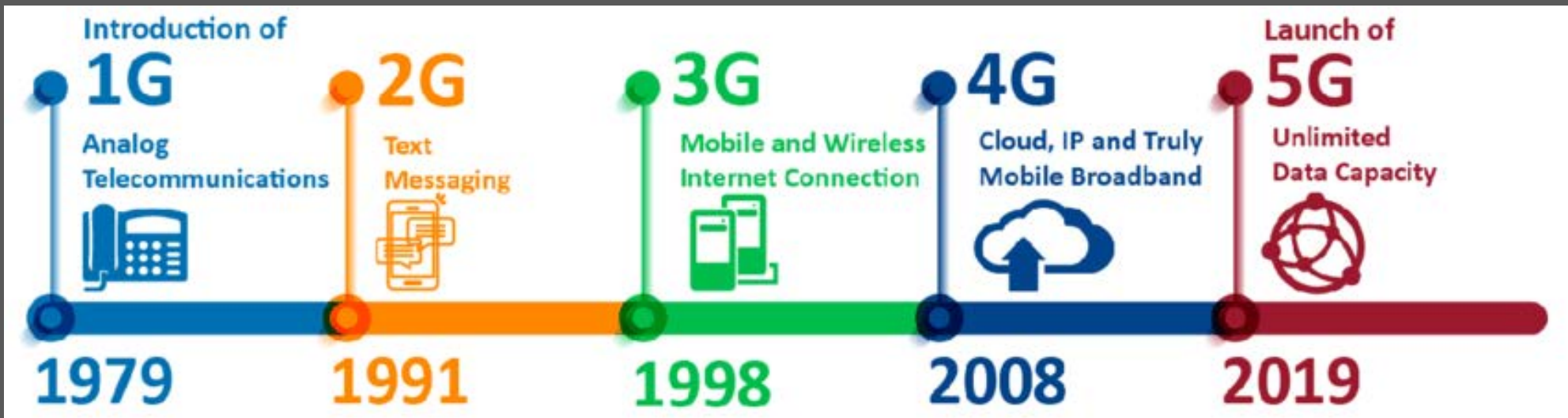




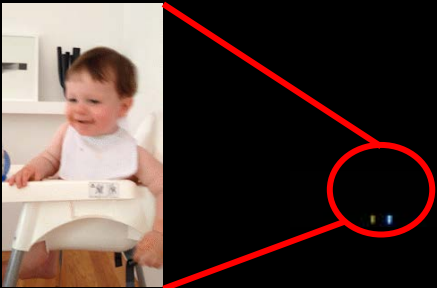
Speeds of between
2 mph (pain) and 200 mph (movement)
Depending on the type of fiber.

3000x increase in bandwidth during adolescence





Increasing
Bandwidth



Meaningful
connectivity

Increasing
Bandwidth

malnutrition

sleep deficits

FOMO

bullying

drug use

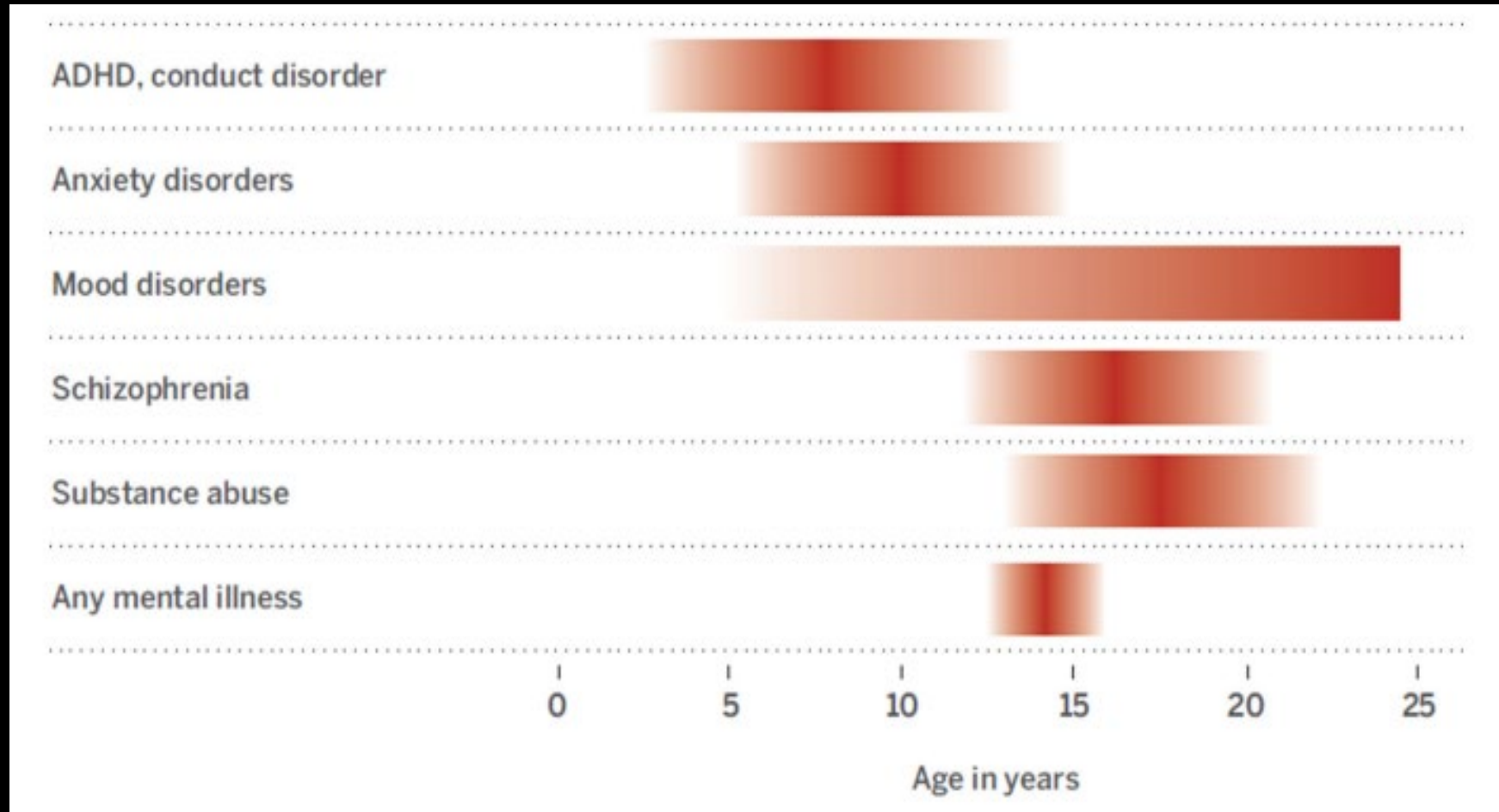
physical
abuse

emotional
neglect

chronic pain



Adolescence is peak time for clinical onset of most mental illnesses





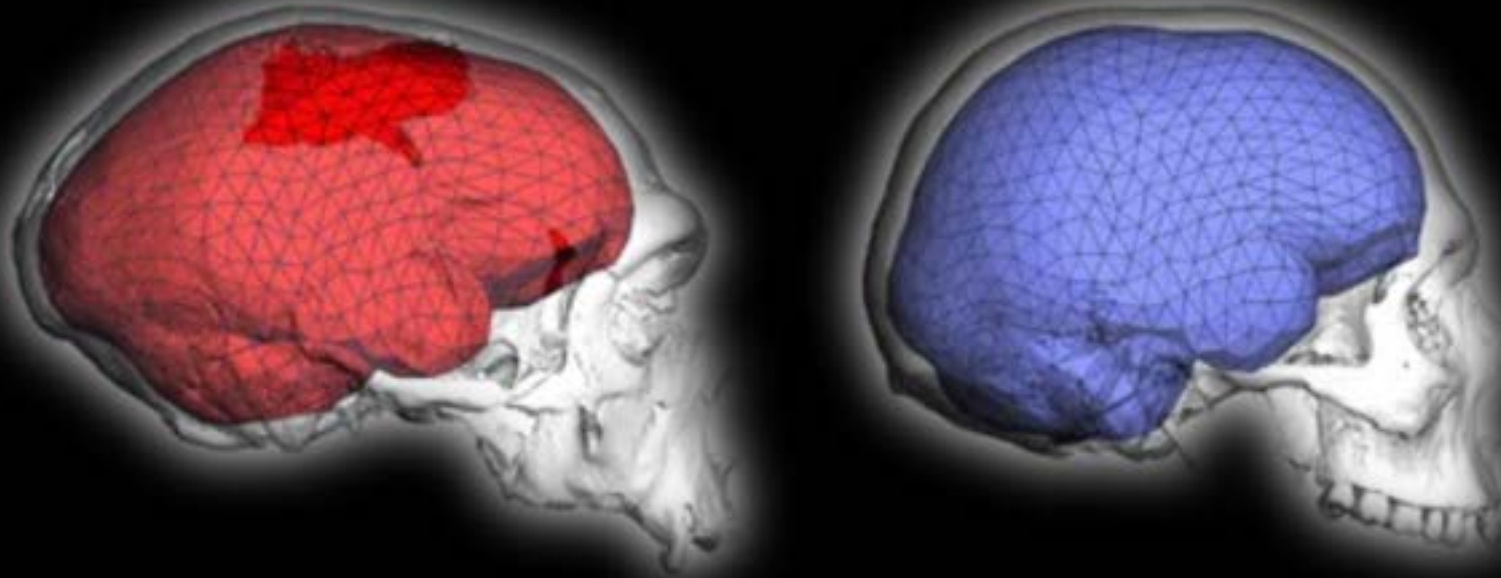
A brain can fail

Evolutionary mismatch

Developmental errors

Overwhelming events

The brain is a product of evolution



elongated

globular

Homo Sapiens: Last 300,000 years

Evolution is all about all adaptation, which is all about trade-offs

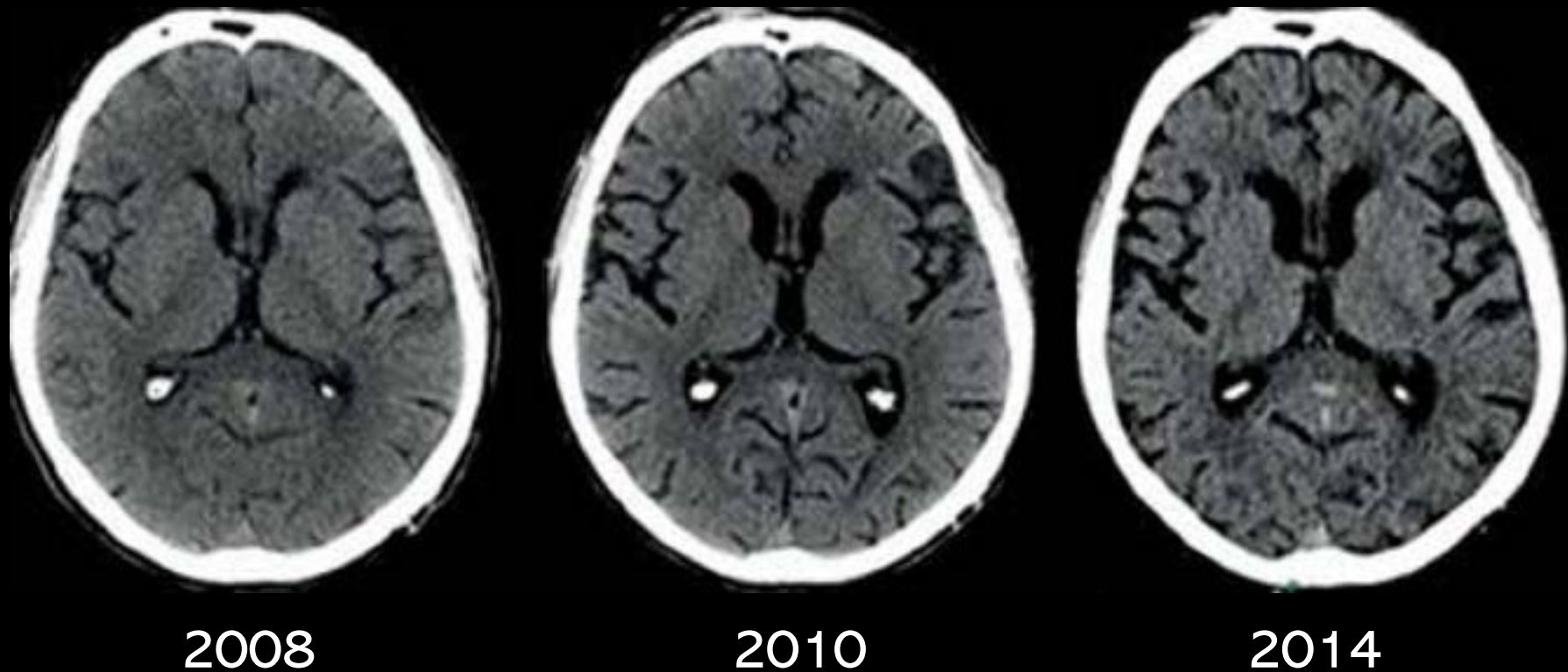


healthy coral

... trade offs also render brains prone to damage and failure

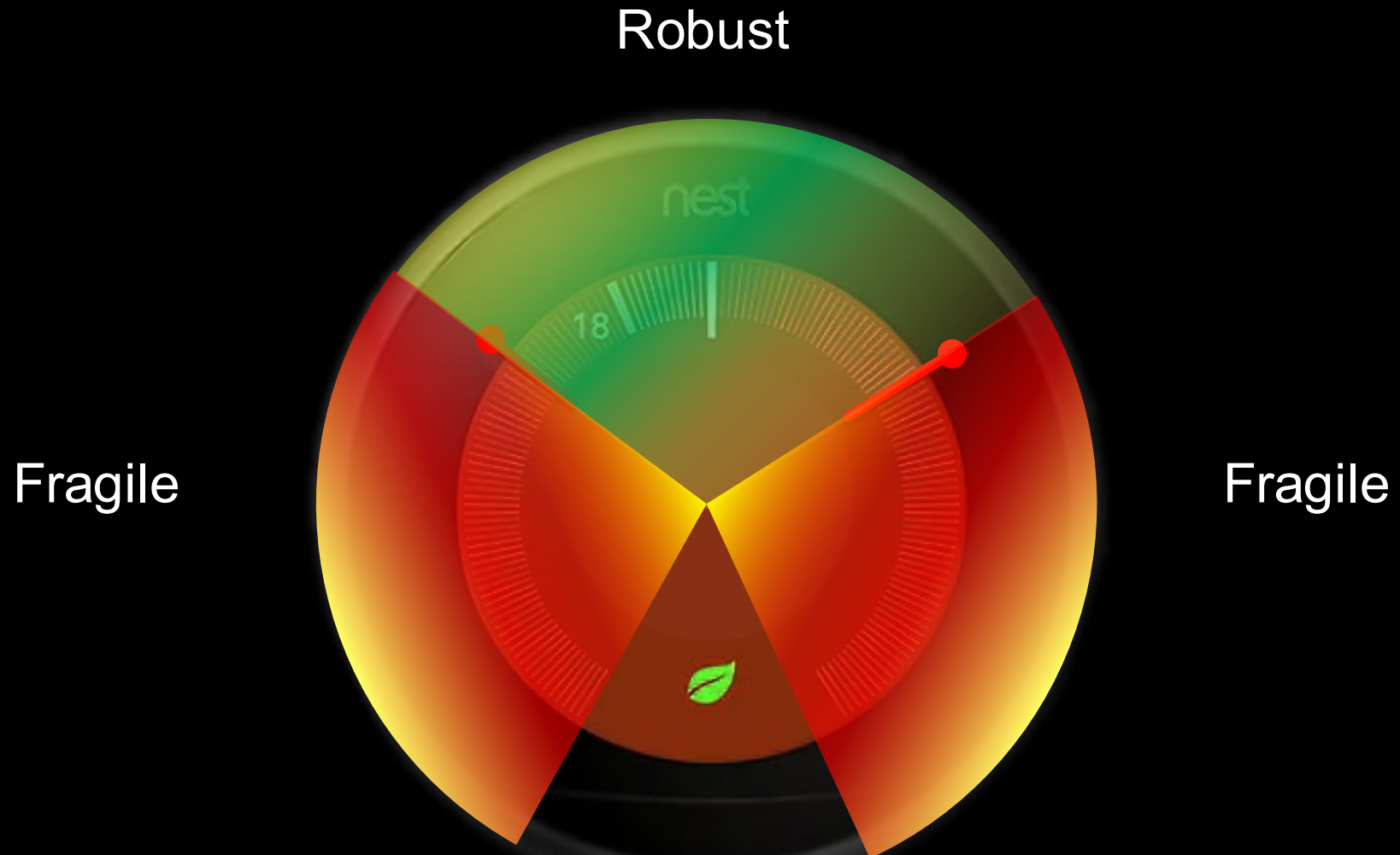


... trade offs also render brains prone to damage and failure



Progressive brain atrophy after years of alcohol exposure

Overwhelming basic control systems



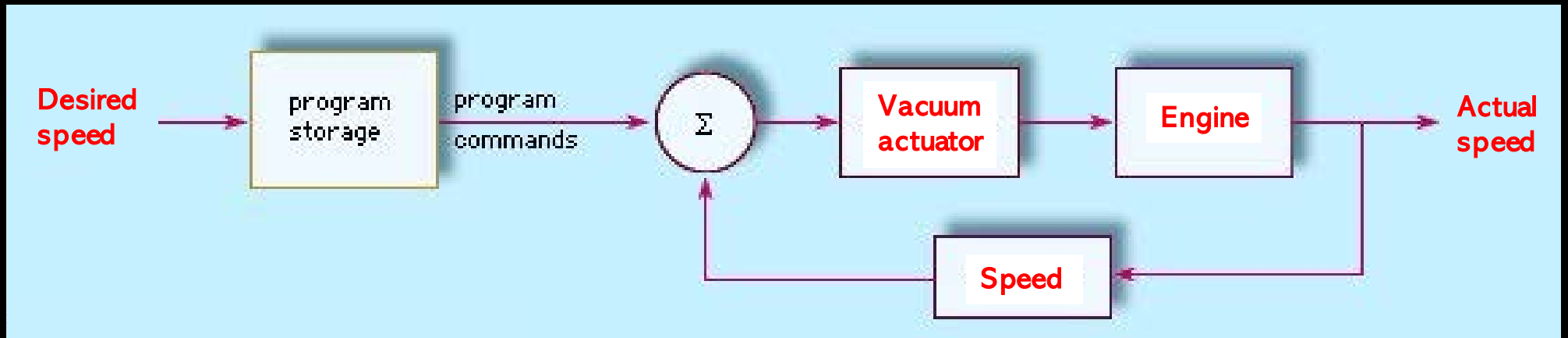
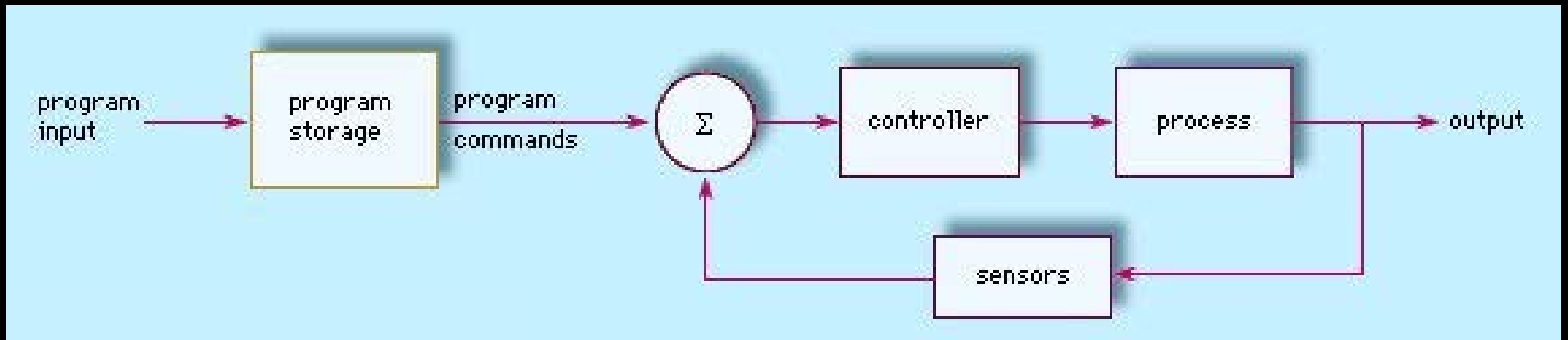
Control systems (like thermostats and cruise controls) are always designed with a set of conditions in mind. Thus, they have limitations



▲ ACC / RES
◀ CRUISE ON / OFF
▼ COAST / SET

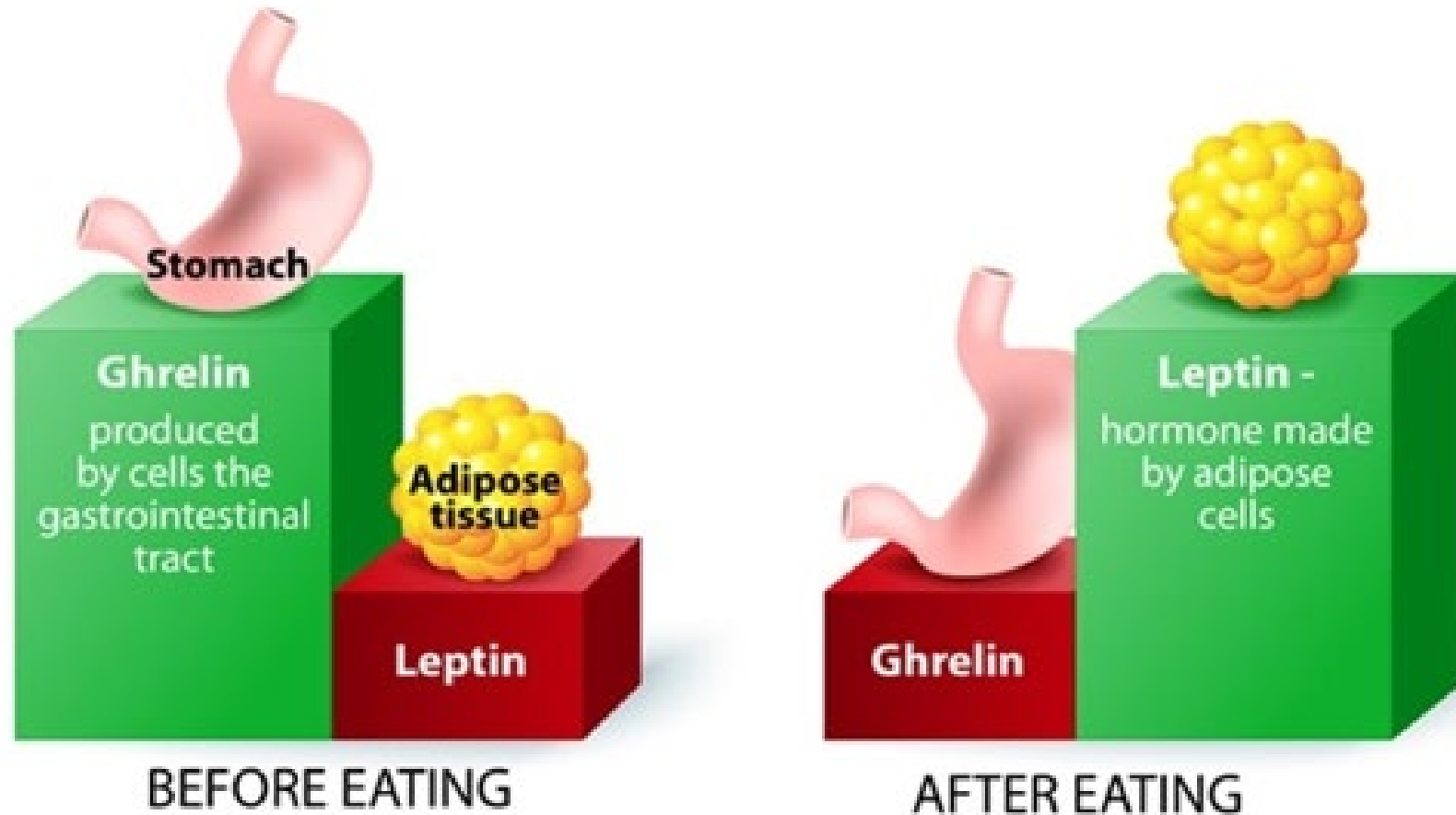
Experts warn not to engage cruise control in heavy traffic, winding roads, slippery pavement, or hilly roads, conditions that could result in loss of vehicle control, serious injury, or death.

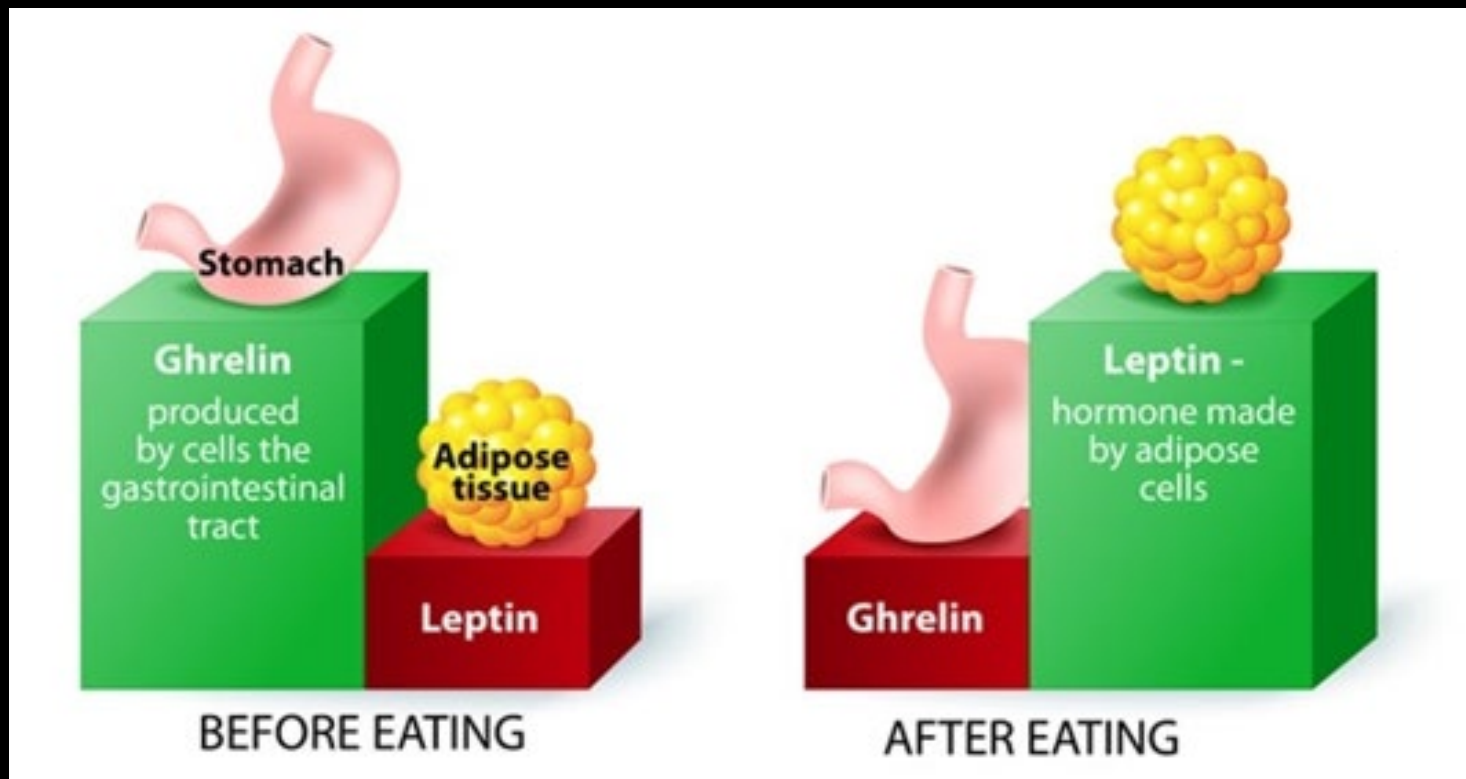
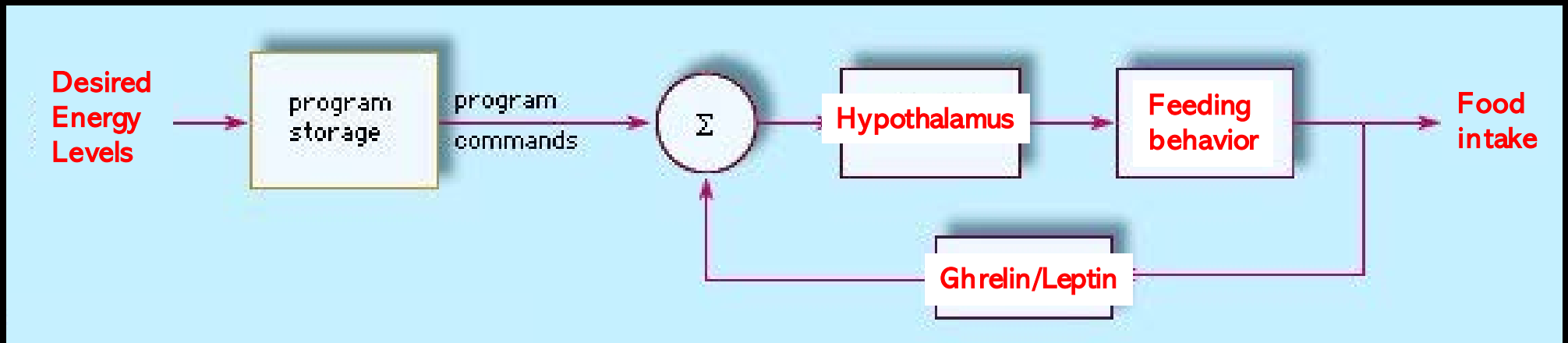
Basic Control Systems



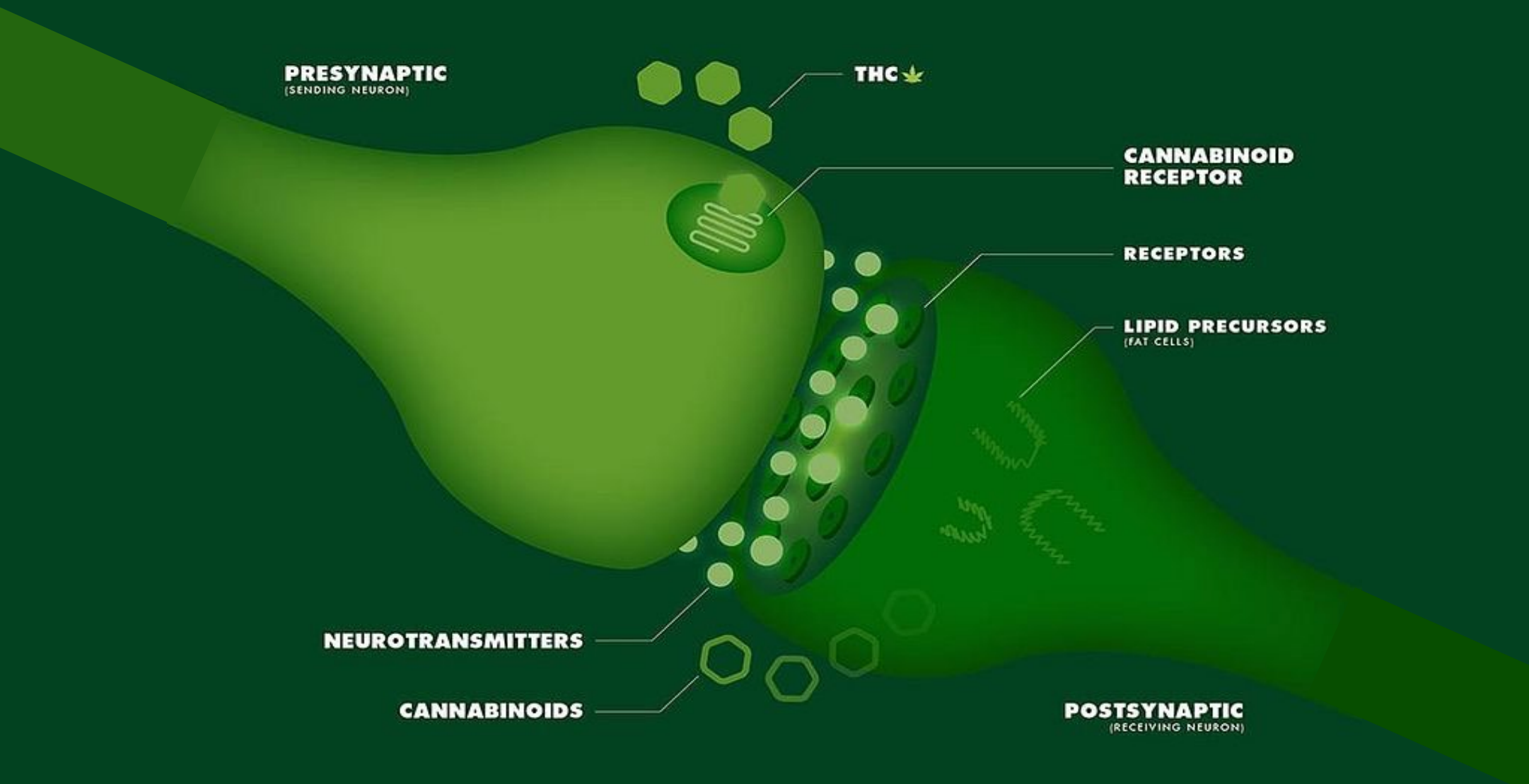
The Energy Balance System

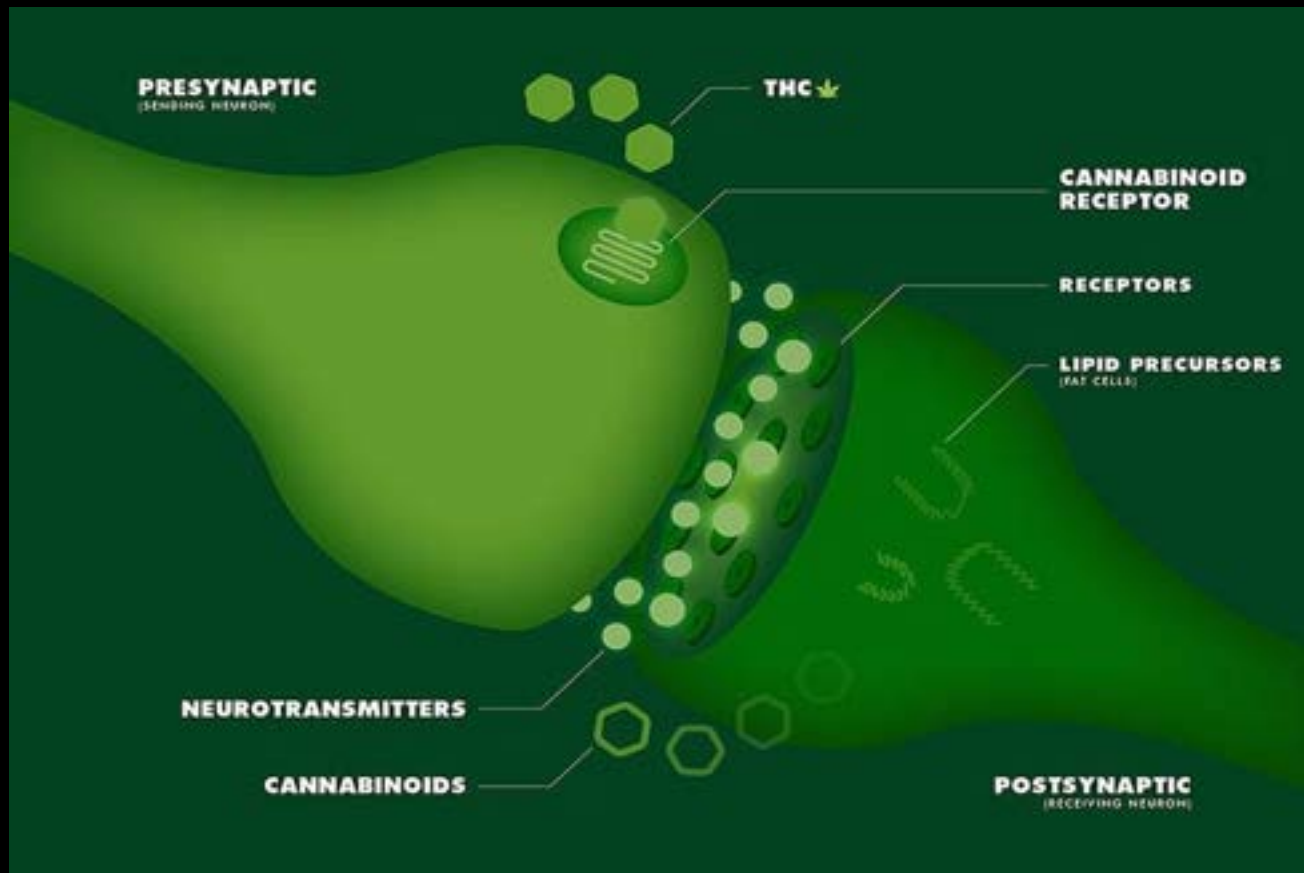
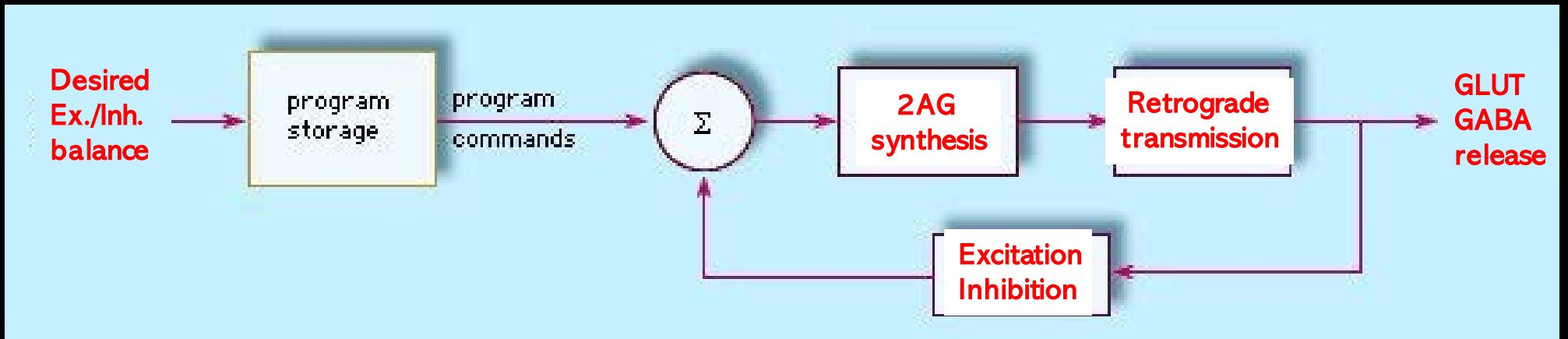
(Controlled cycles of energy intake and expenditure)





The Endocannabinoid System (on demand control of neurotransmission)



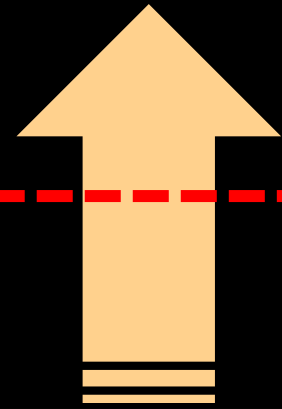
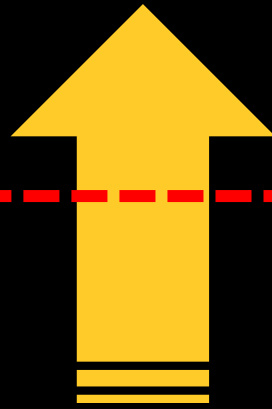
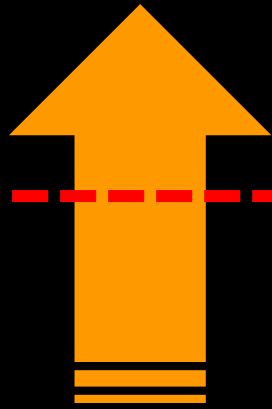


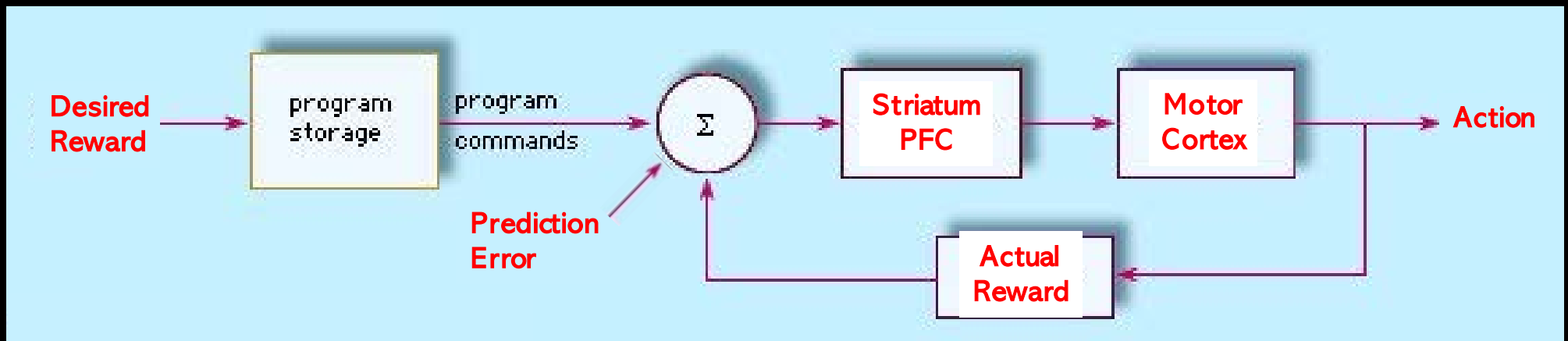
Goal-Directed Behaviors

Reward Value

Motivation

Cost/Benefit





Discrepancies between actual and expected outcomes can be used for learning.

If the learning process proceeds within the robust region of this particular basic control system the result is adaptive, goal directed learning.

However, if the process veers off into the regions of fragility the learning can turn maladaptive and shift from goal-directed to maladaptive, or compulsive, or addictive behaviors.



Constant
speed



Energy
balance



Neural
activity



Reward
learning



Speed
Data

Ghrelin
Leptin

Endo
cannabinoids

Dopamine

- The human brain
- **The effect of addictive drugs**
- Interindividual differences in risk
- Boosting resilience

Dopamine





Drugs reset/wreak havoc with the dopamine thermostat

BUT WHY??

What does dopamine do?

It teaches the brain about:

What does that mean?

DA mediates the process by which we become able to use past and current events (*) to predict what the future holds.

(*) rewarding and/or novel events.

The Dopamine Thermostat

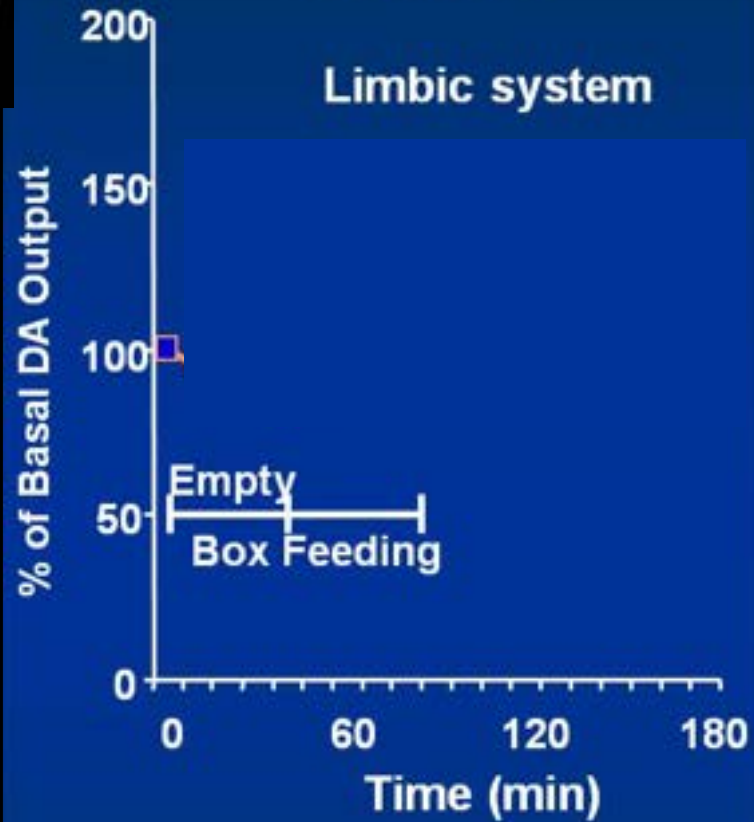
(A Basic Control System for Reward Learning)





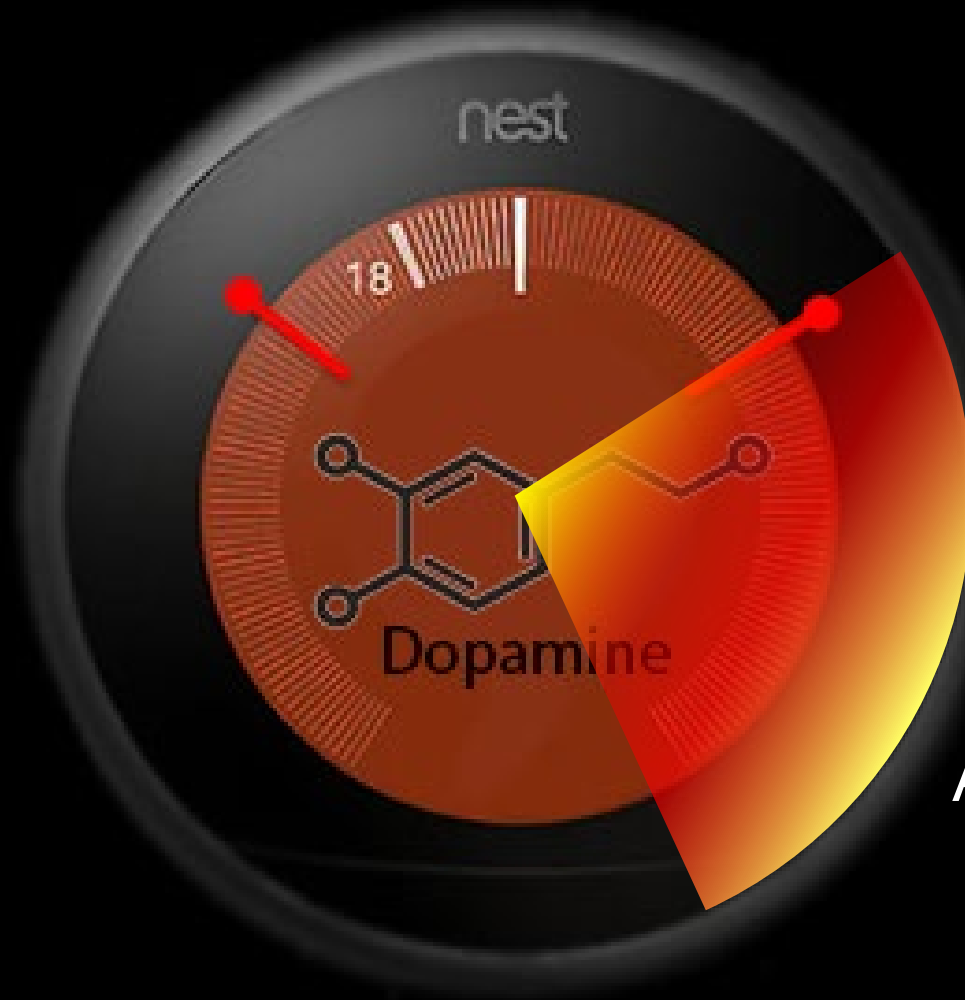
FOOD

Limbic system



Di Chiara et al.
(1999)

Overwhelming the Dopamine Control System



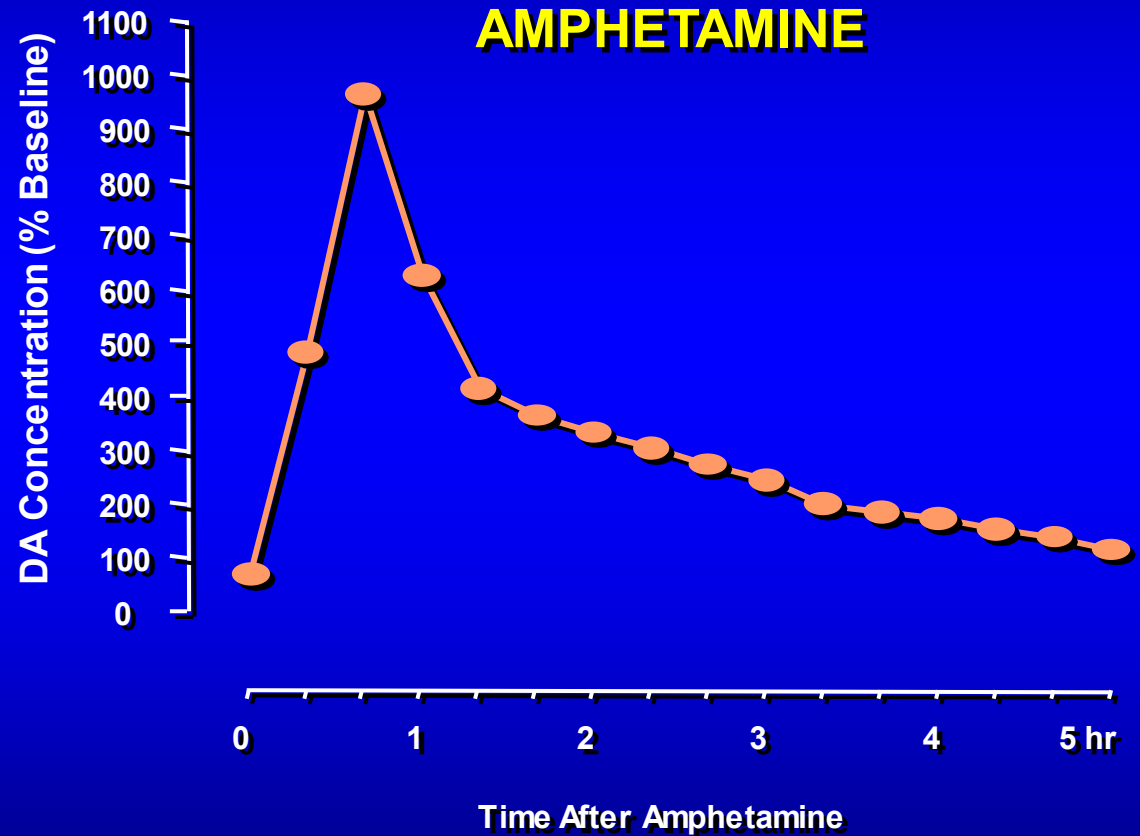
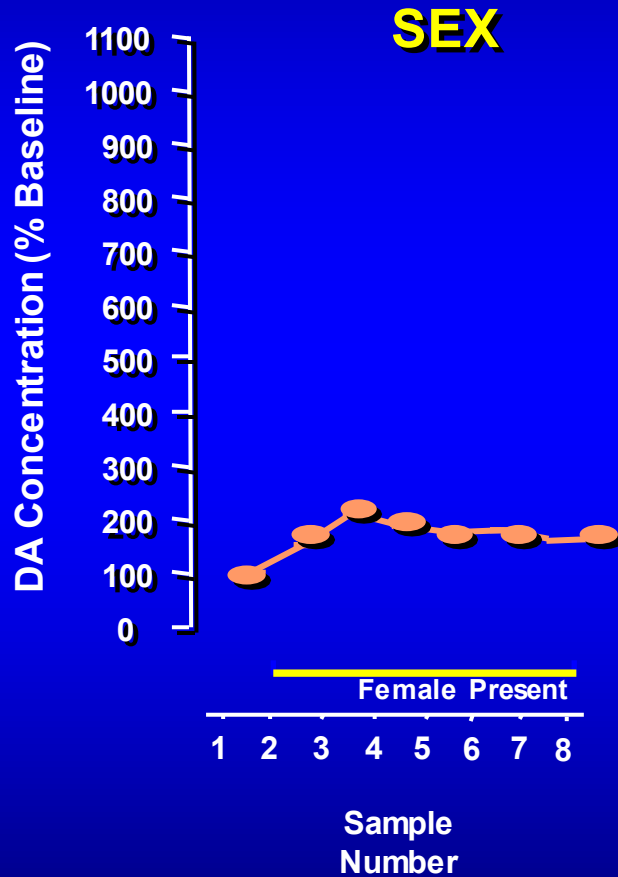
Fragile



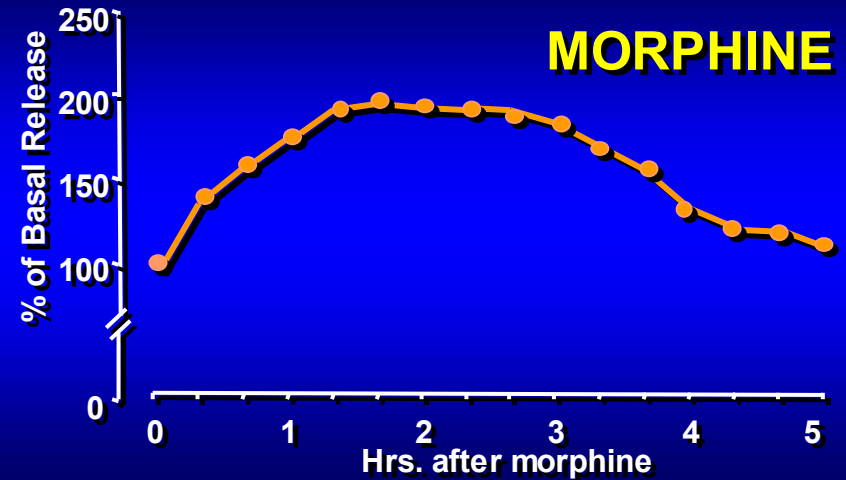
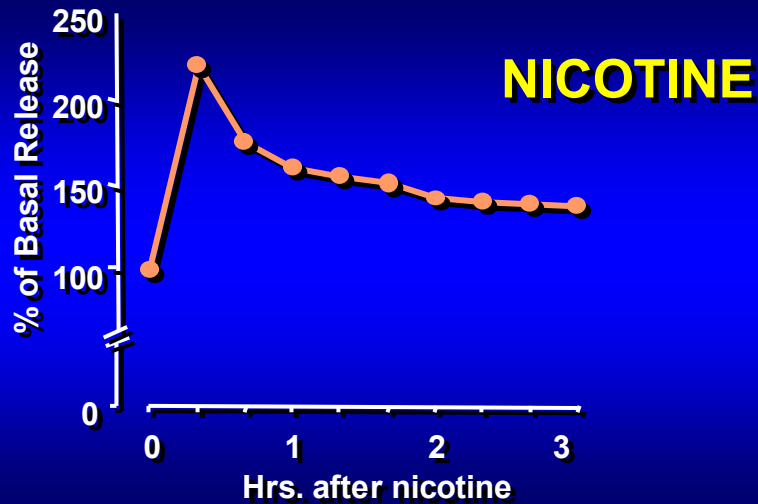
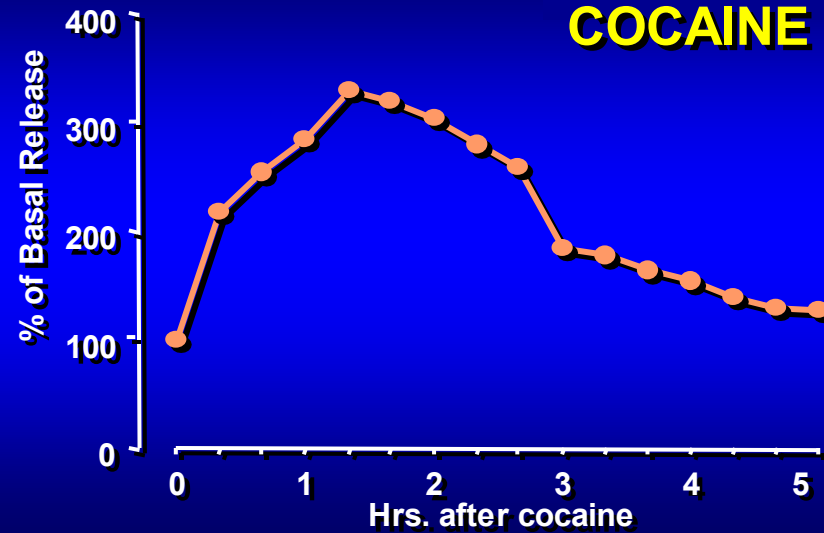
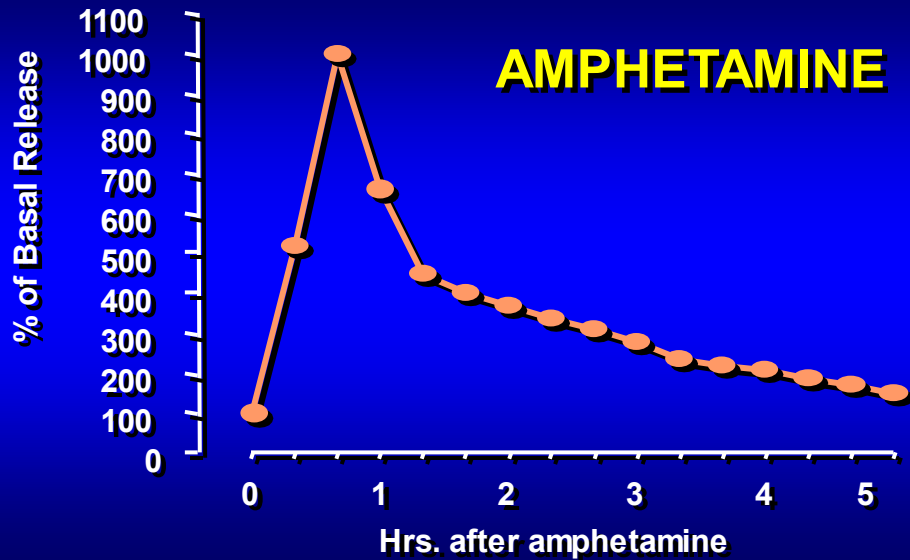
Acute (early) effects
Of substance use

Natural Rewards Elevate Dopamine Levels

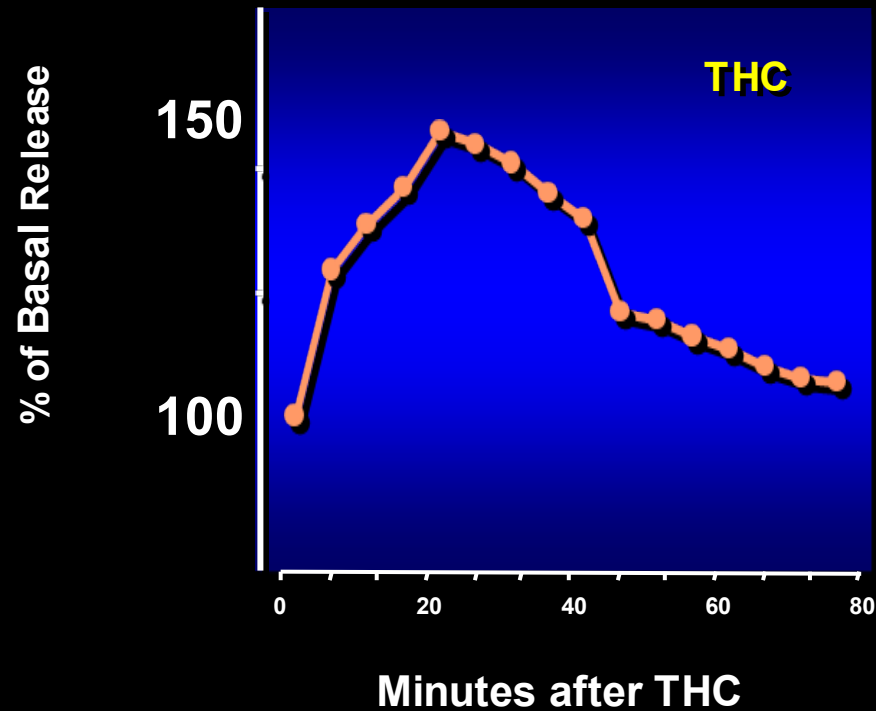
But Drugs are amazingly more effective



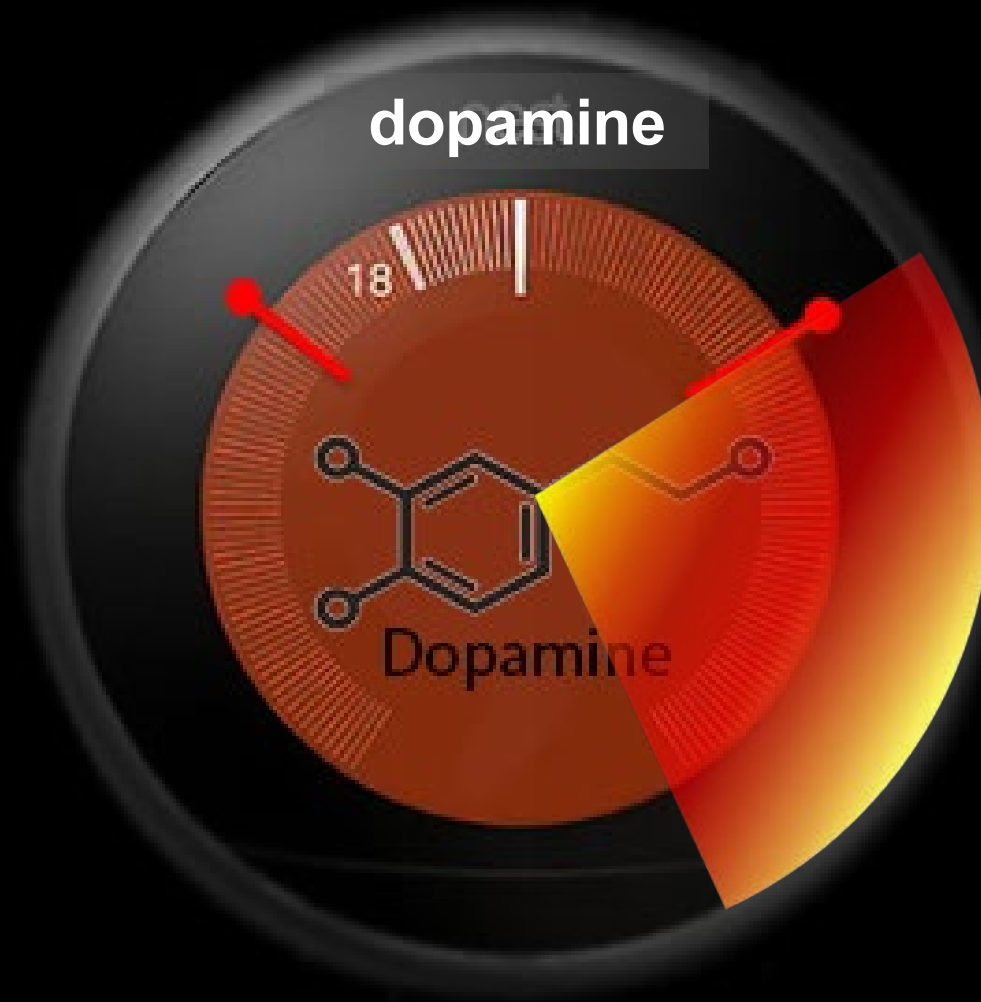
Effects of Drugs on Dopamine Release (DA in Accumbens)



Effect of THC on DA release In the reward circuit



Overwhelming the Dopamine Control System



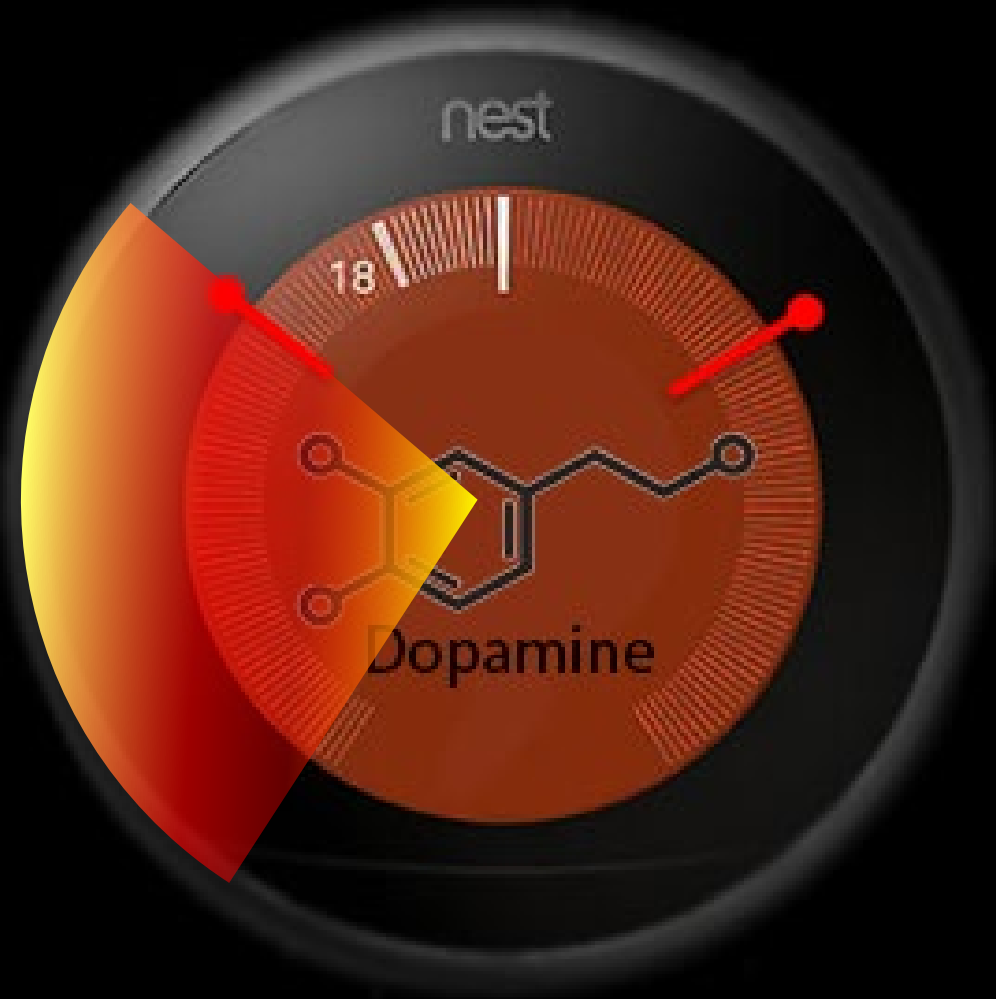
Fragile



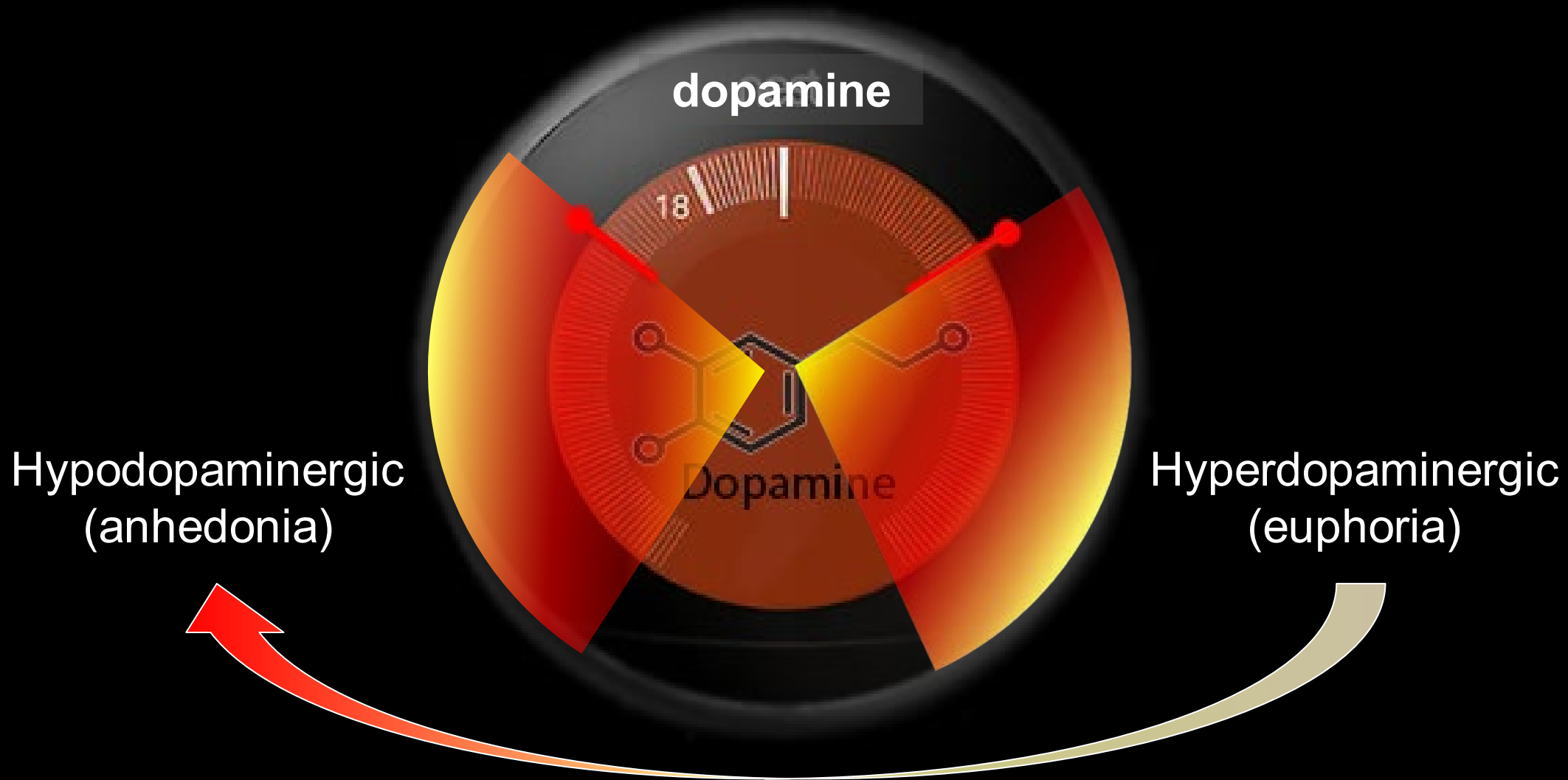
Early effects of
substance use

Overwhelming the Dopamine Control System

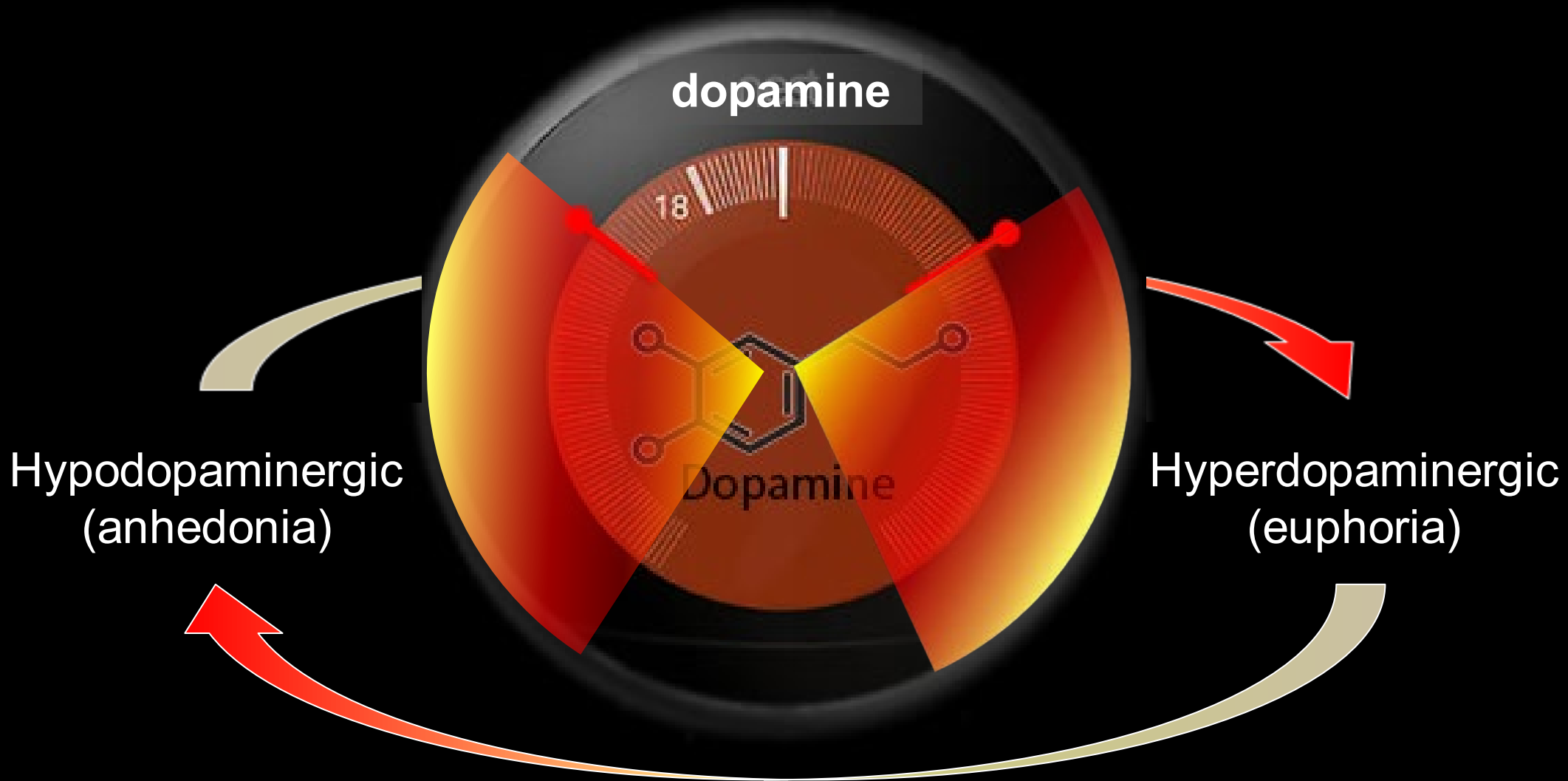
Fragile
↓
Late stage
of addiction



Overwhelming the Dopamine Control System



Overwhelming the Dopamine Control System



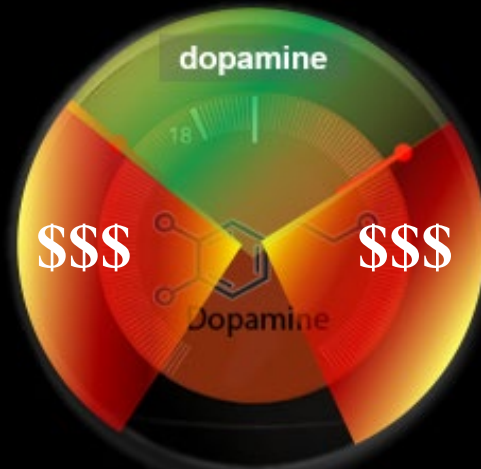
**FOOD INDUSTRY
(UPF)**



**TECH COMPANIES
(SM platforms)**

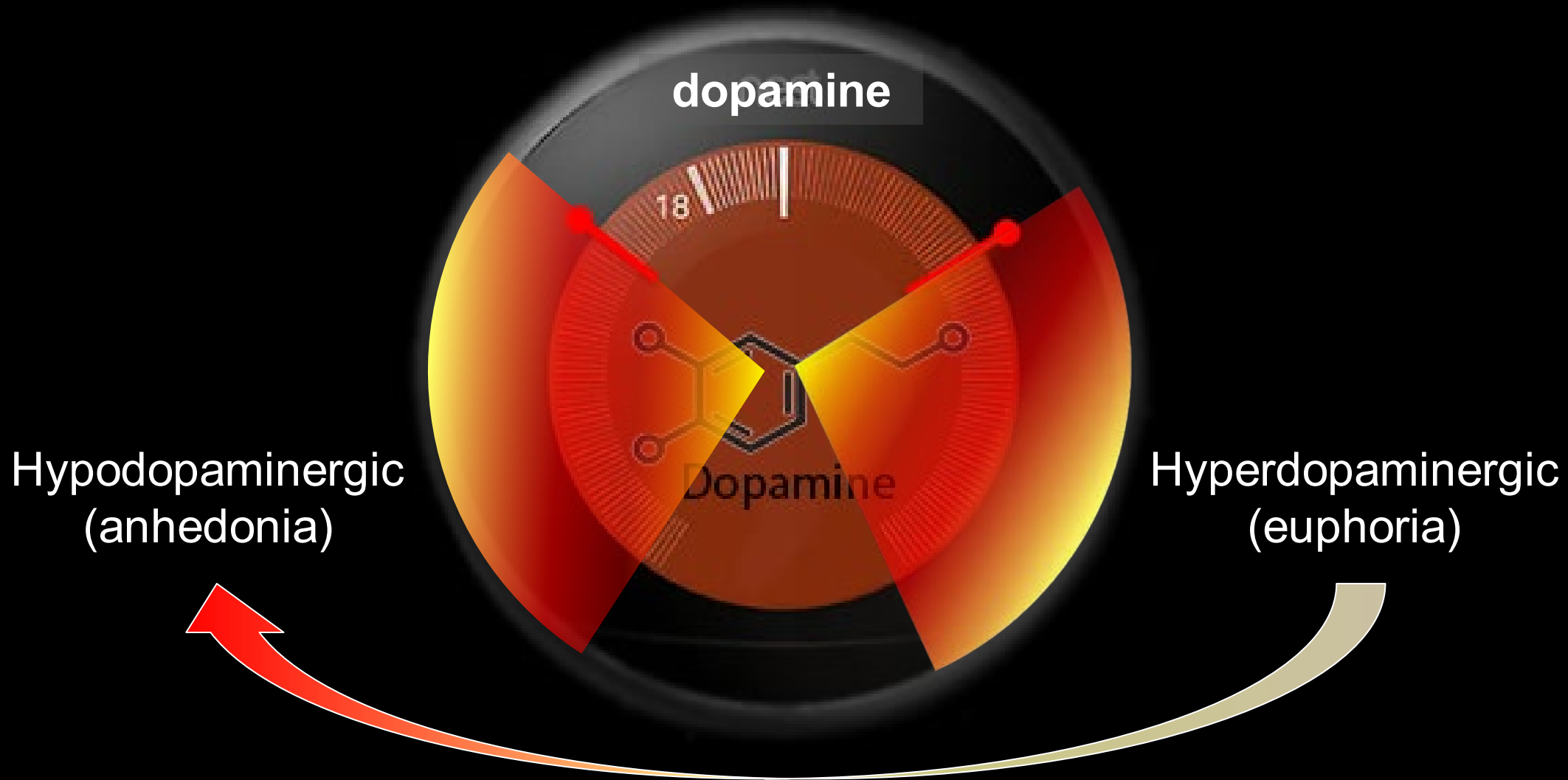


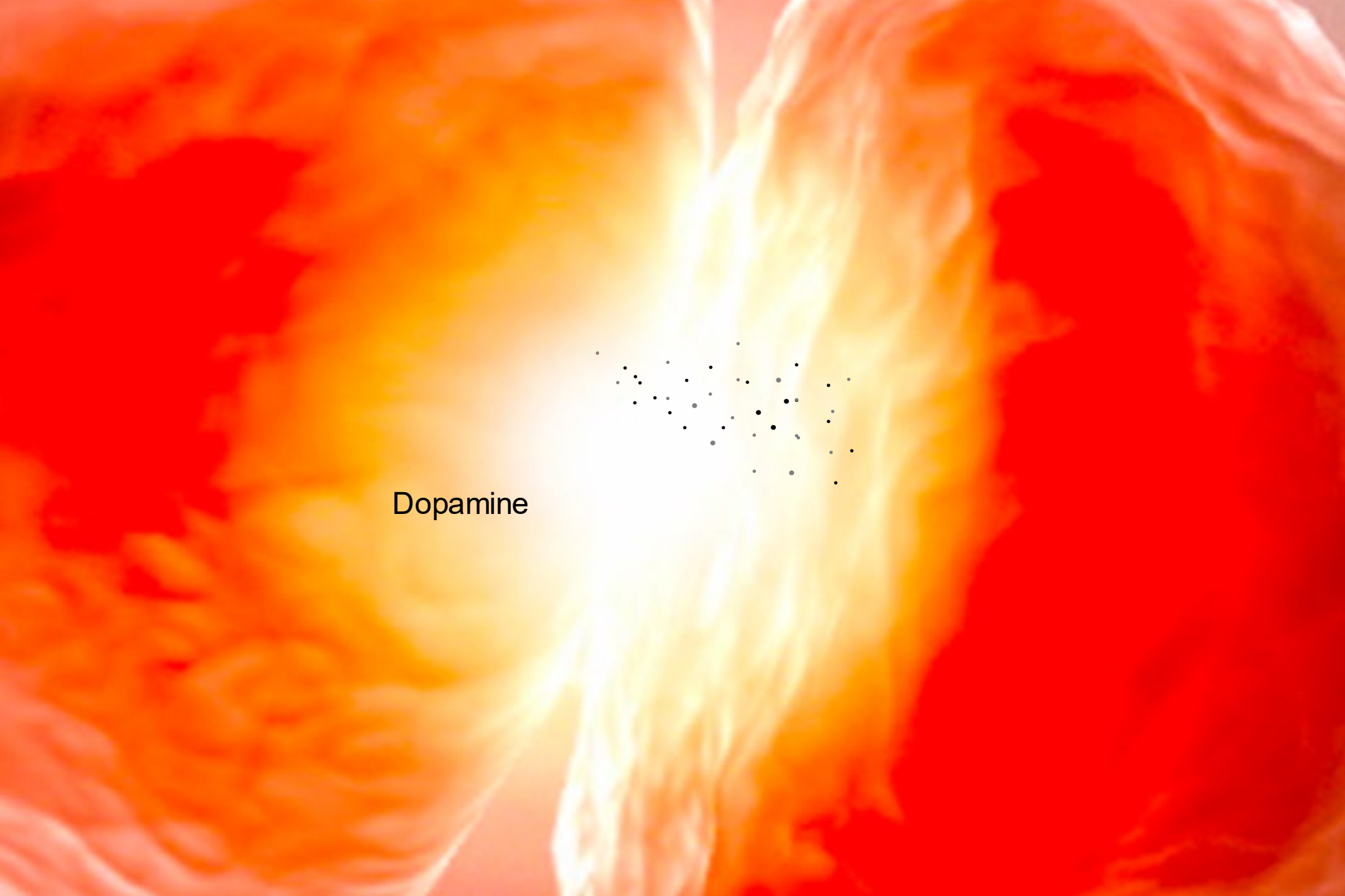
**PHARMA Co.
(Oxycodone)**



MONETIZATION OF THE DOPAMINE THERMOSTAT

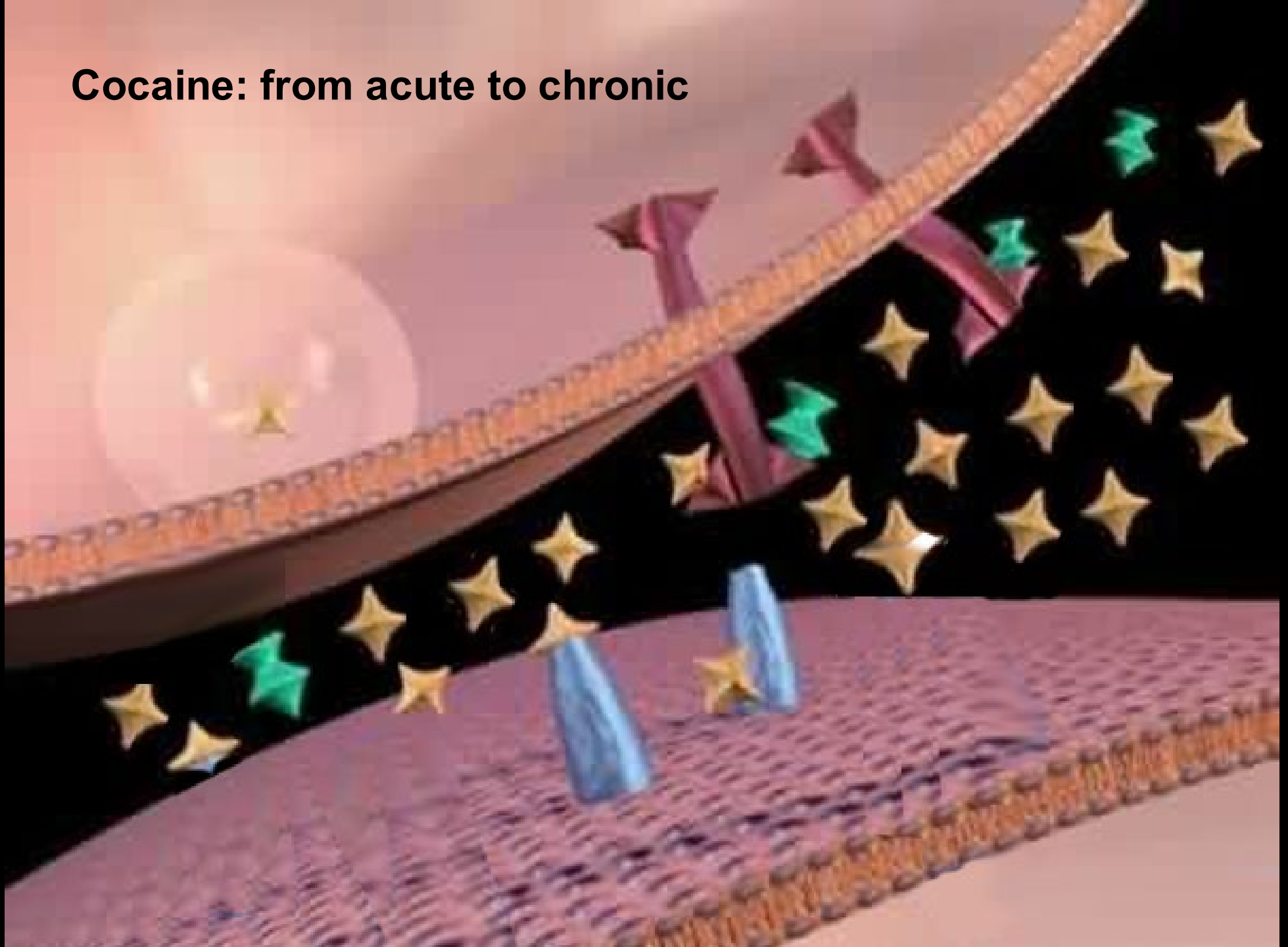
Overwhelming the Dopamine Control System





Dopamine

Cocaine: from acute to chronic



Dopamine Receptor level is Lower in Addiction



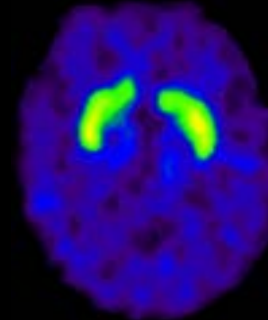
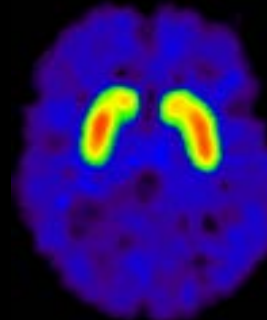
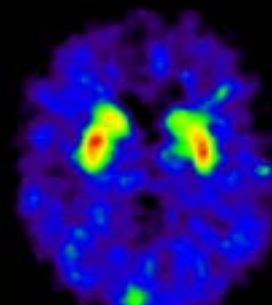
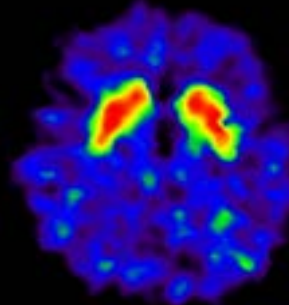
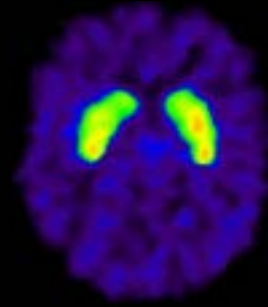
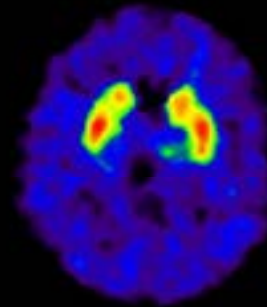
Cocaine



Alcohol

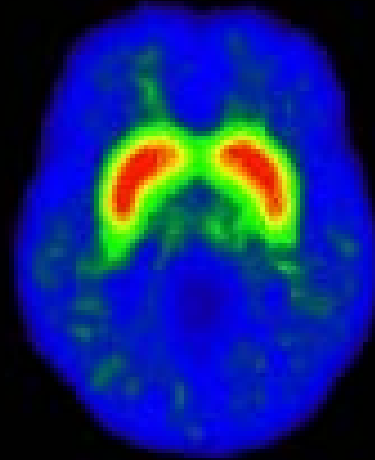


Heroin

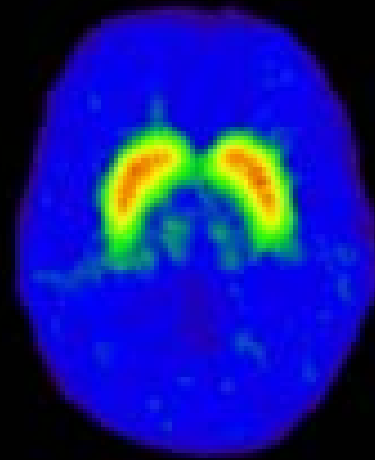


control

addicted

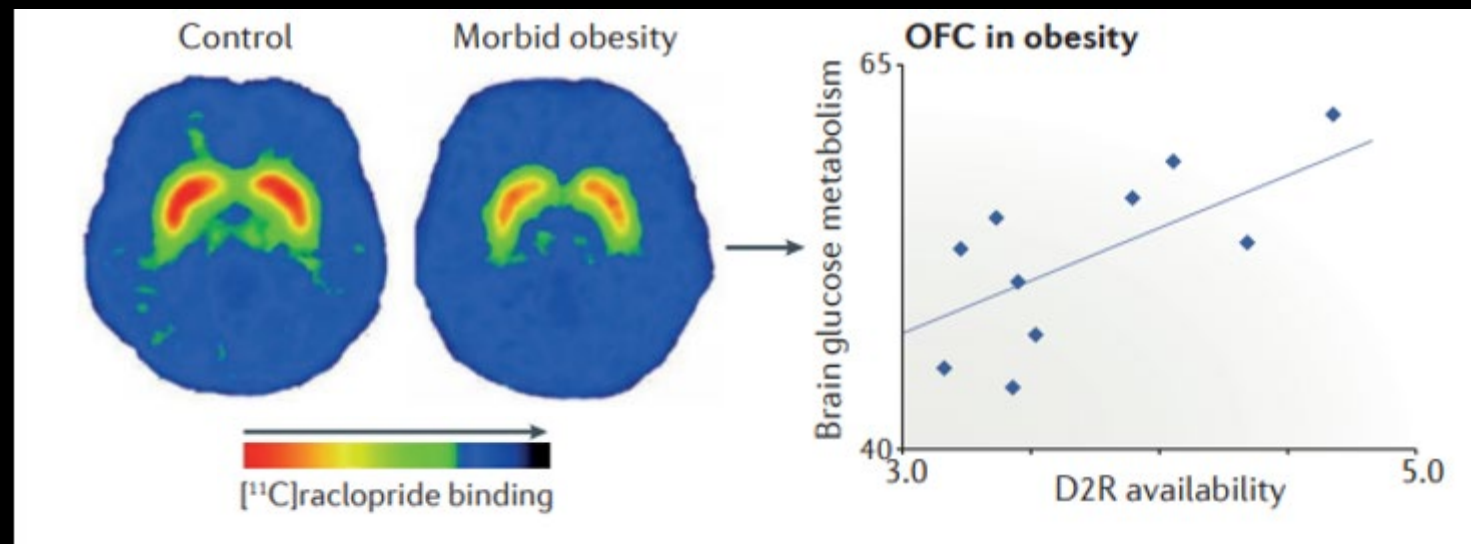
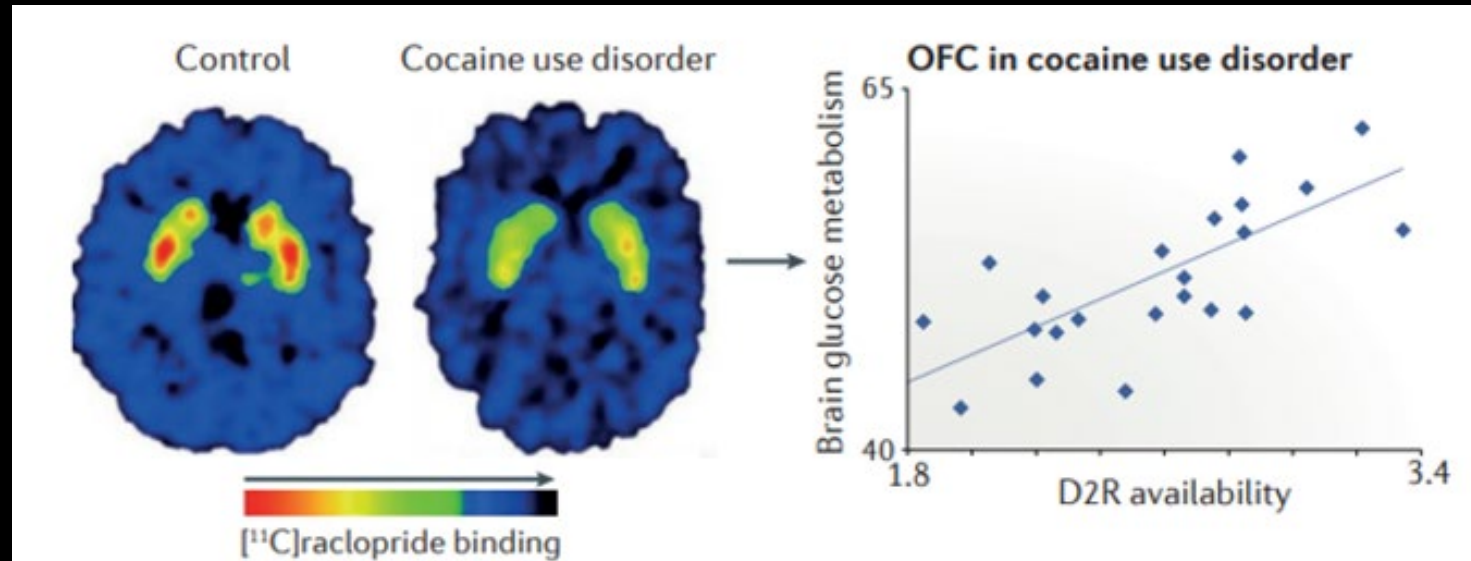


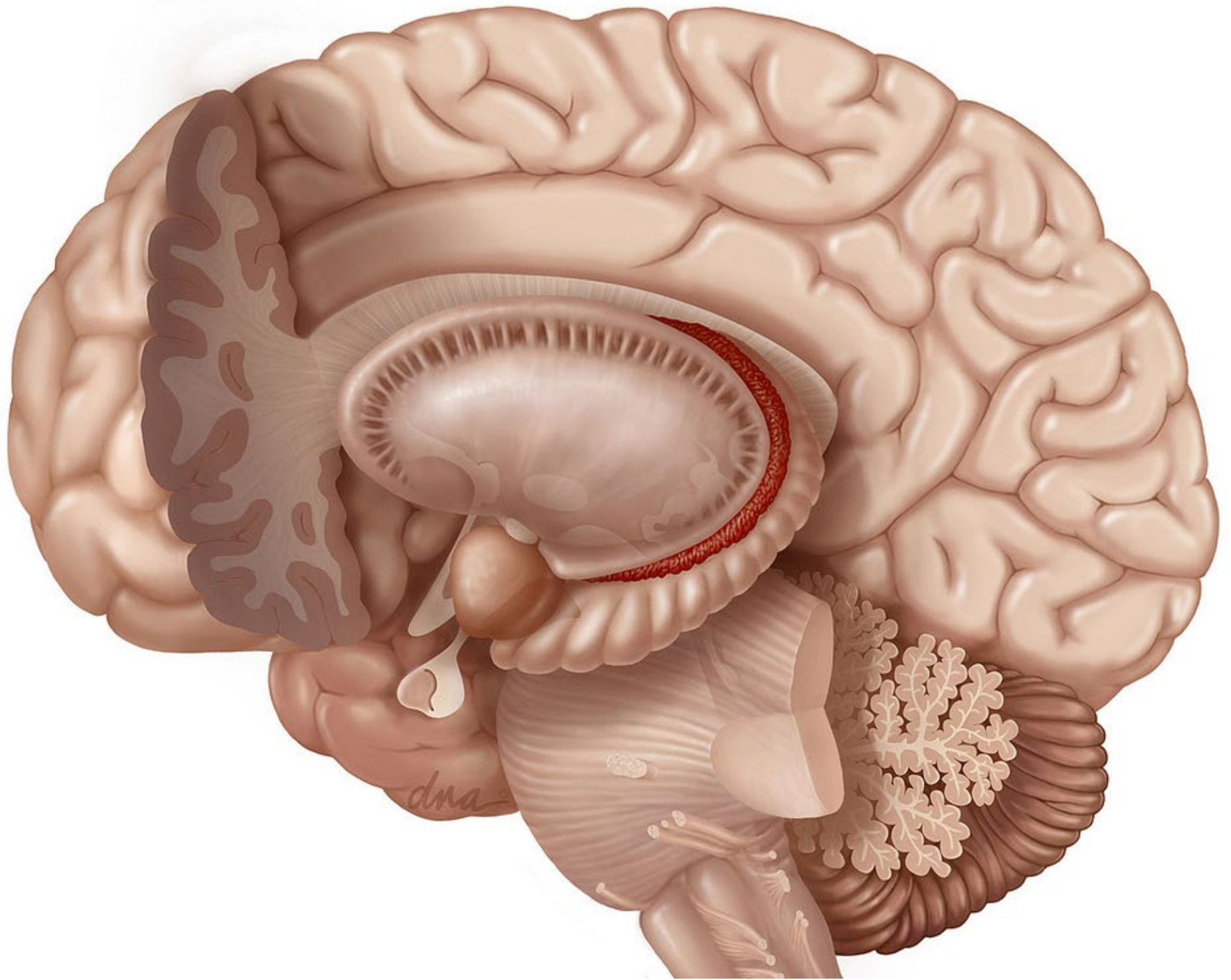
Control Subjects
Average BMI: 24.7



Obese Subjects
Average BMI: 51.2

Lower D2R availability correlates with lower Glucose metabolism (OFC)

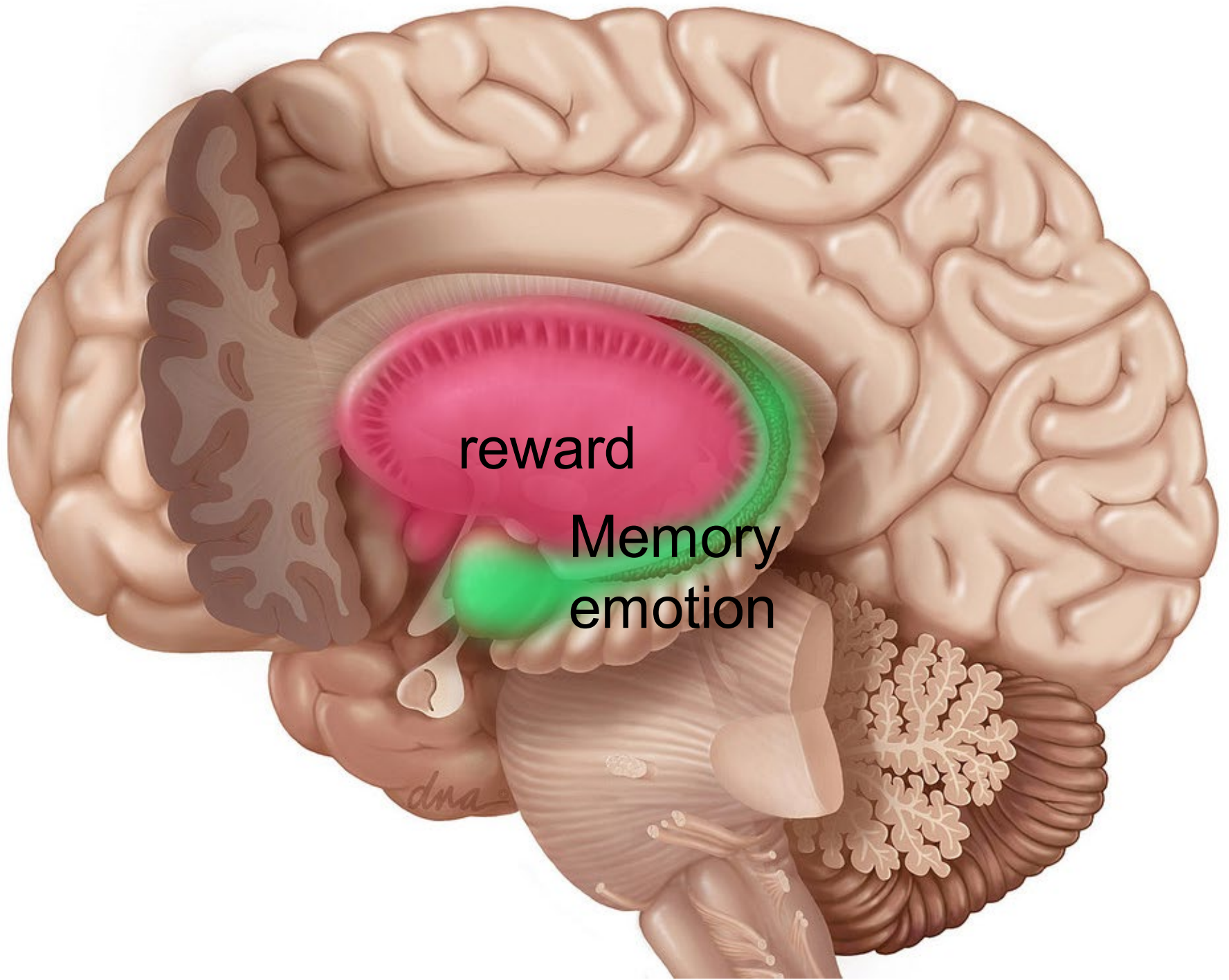






reward

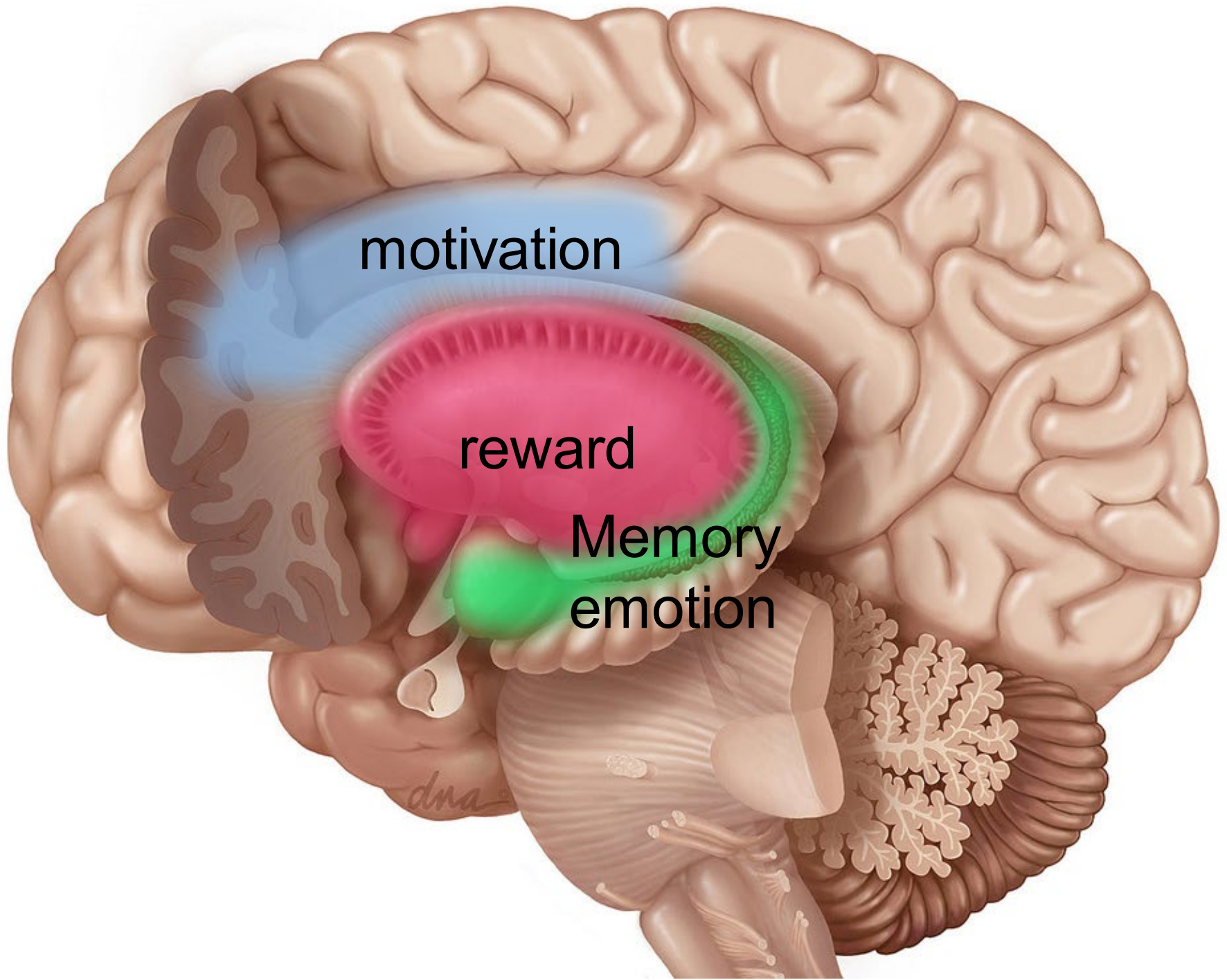
dna



reward

Memory
emotion

dna

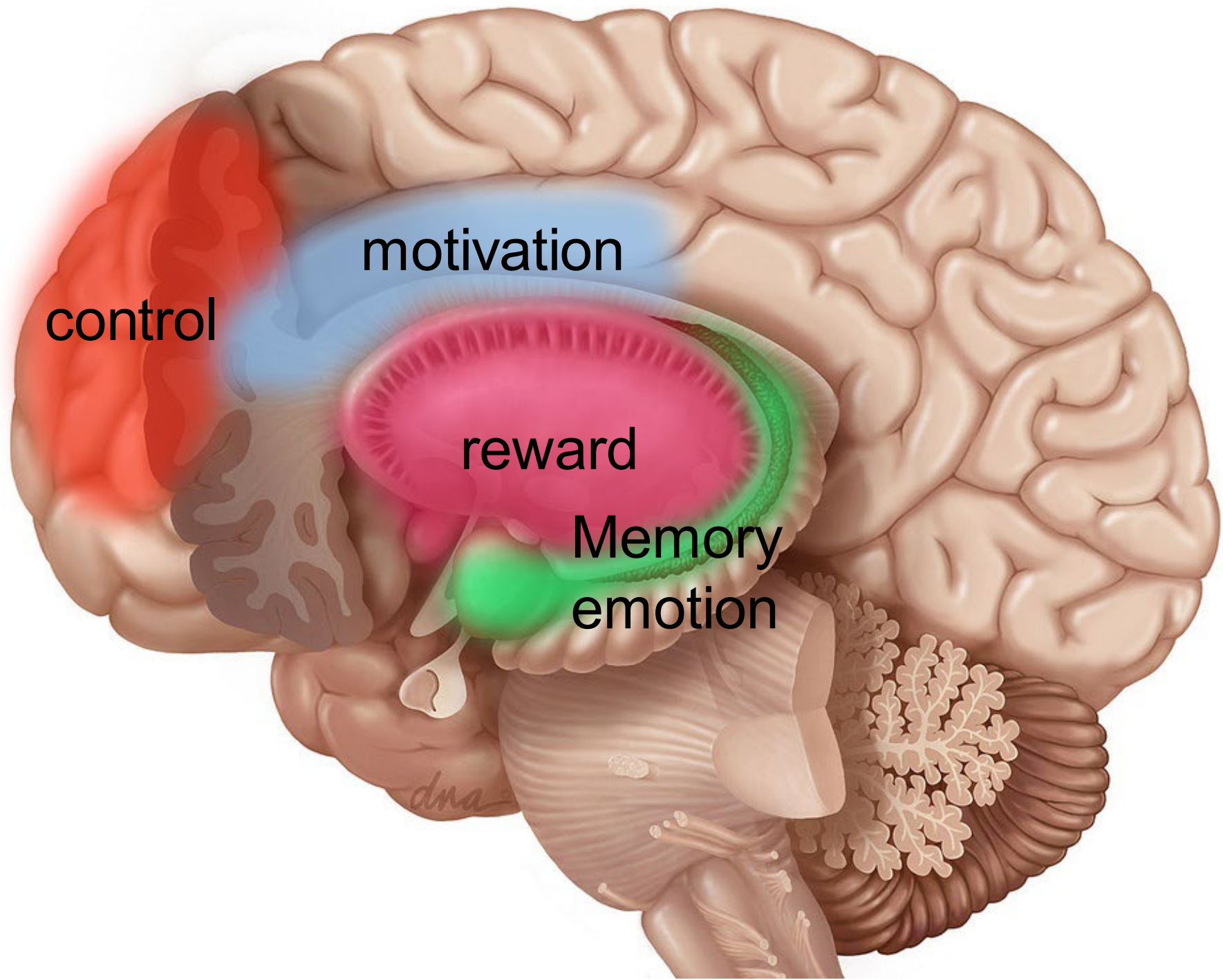


motivation

reward

Memory
emotion

dna



control

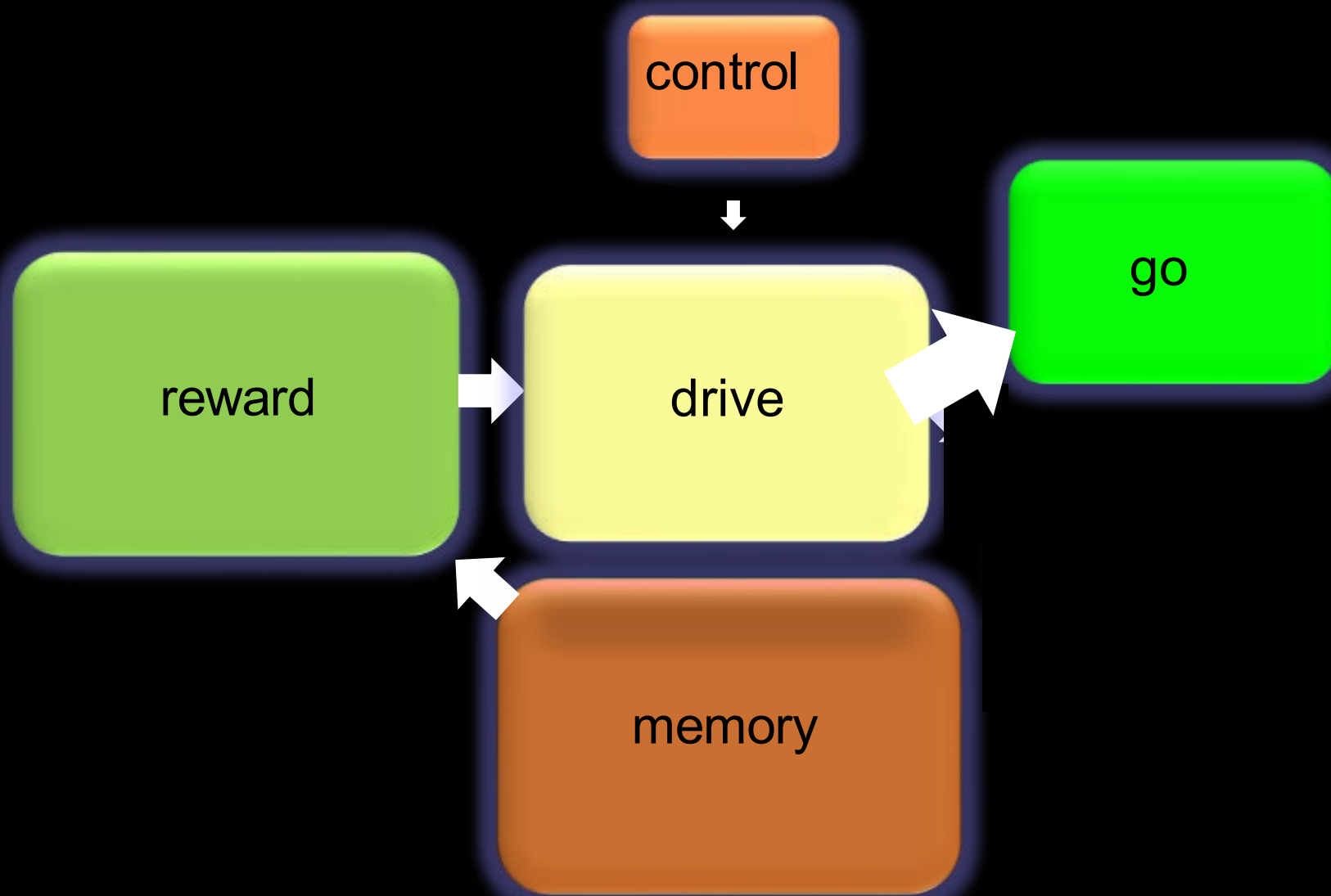
motivation

reward

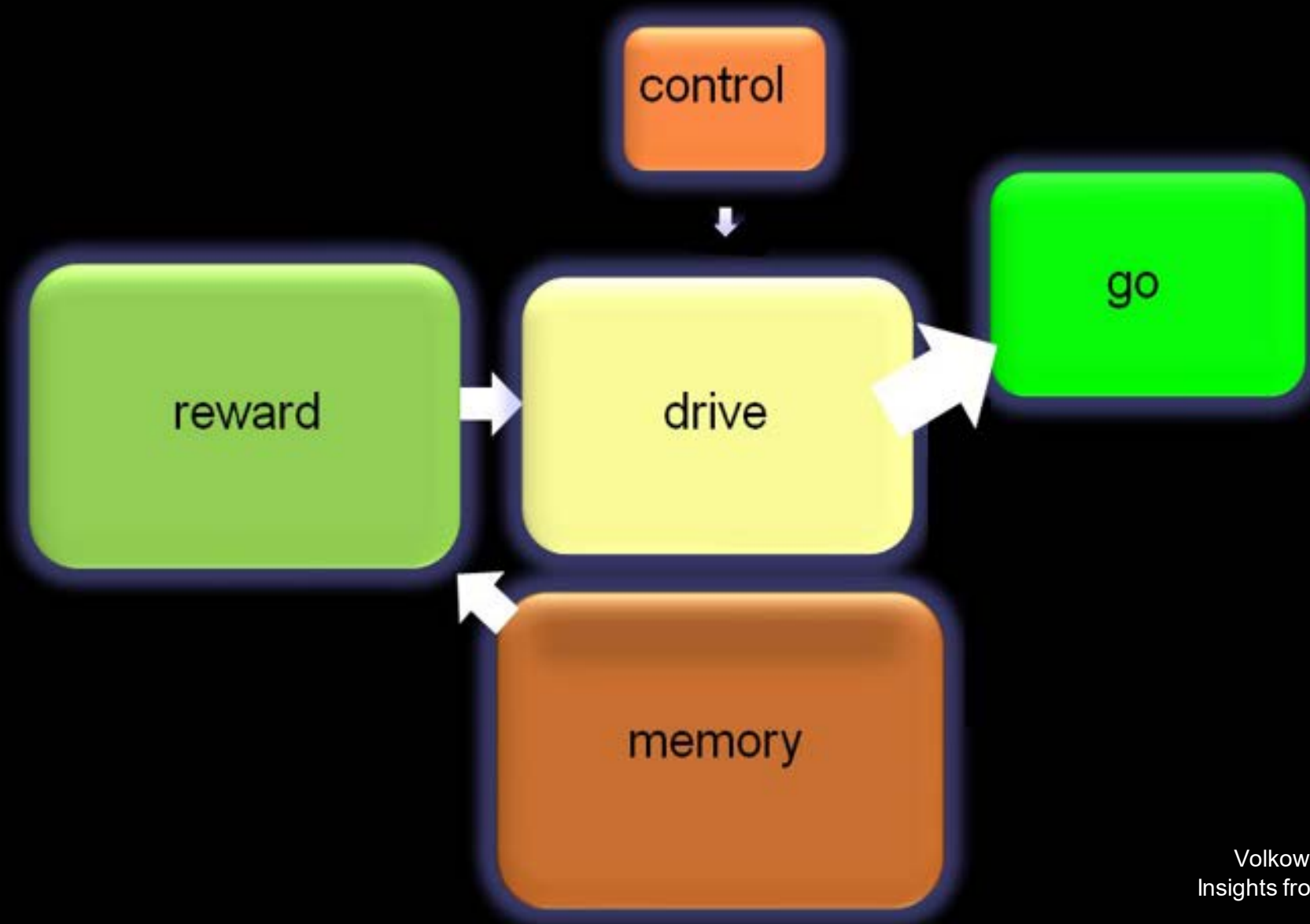
Memory
emotion

dna

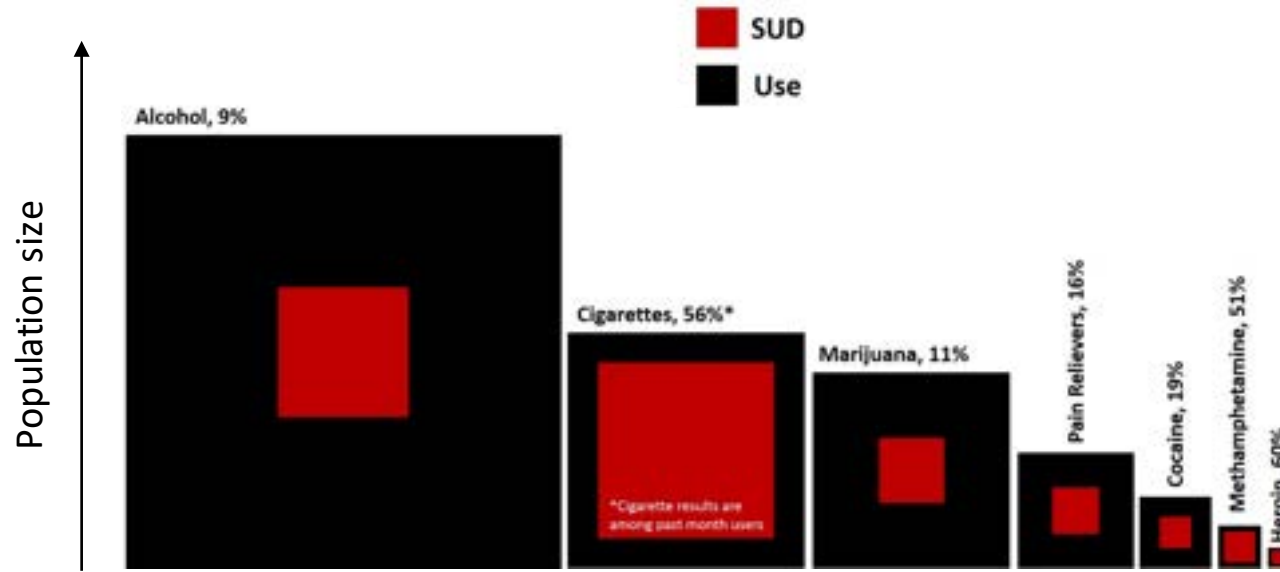
Addicted brain



It's a moral failure



A

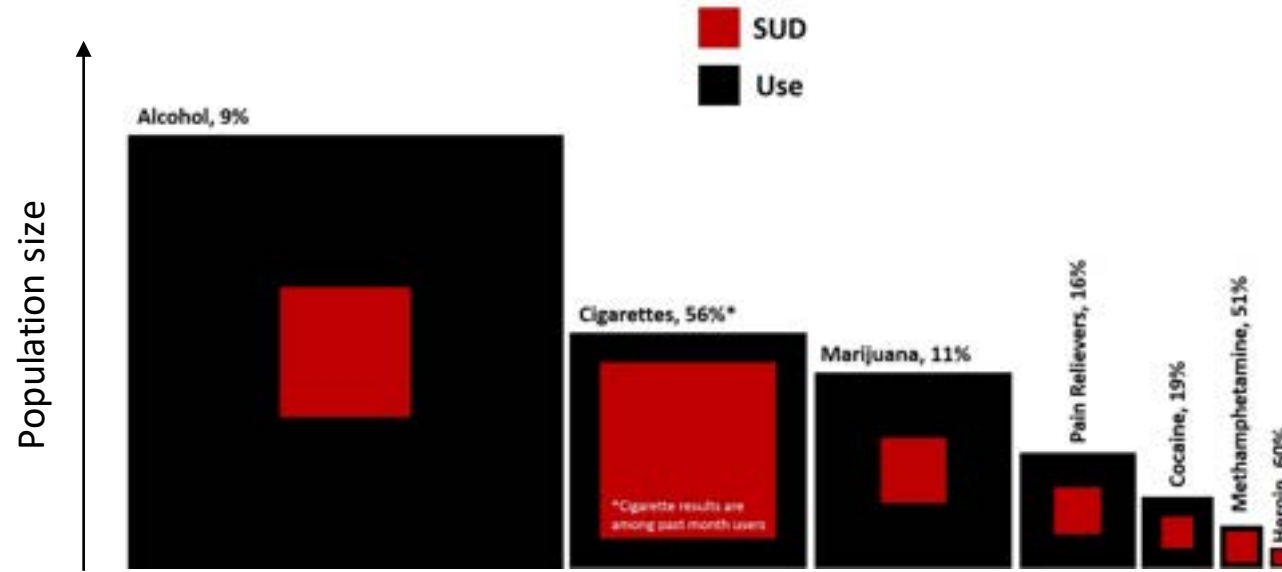


US Prevalence of use and SUD

Drug related mortality

US Prevalence of use and SUD

A



- The human brain
- The effect of addictive drugs
- **Interindividual differences in risk**
- Boosting resilience

The Swiss Cheese Model of Addiction



genetics

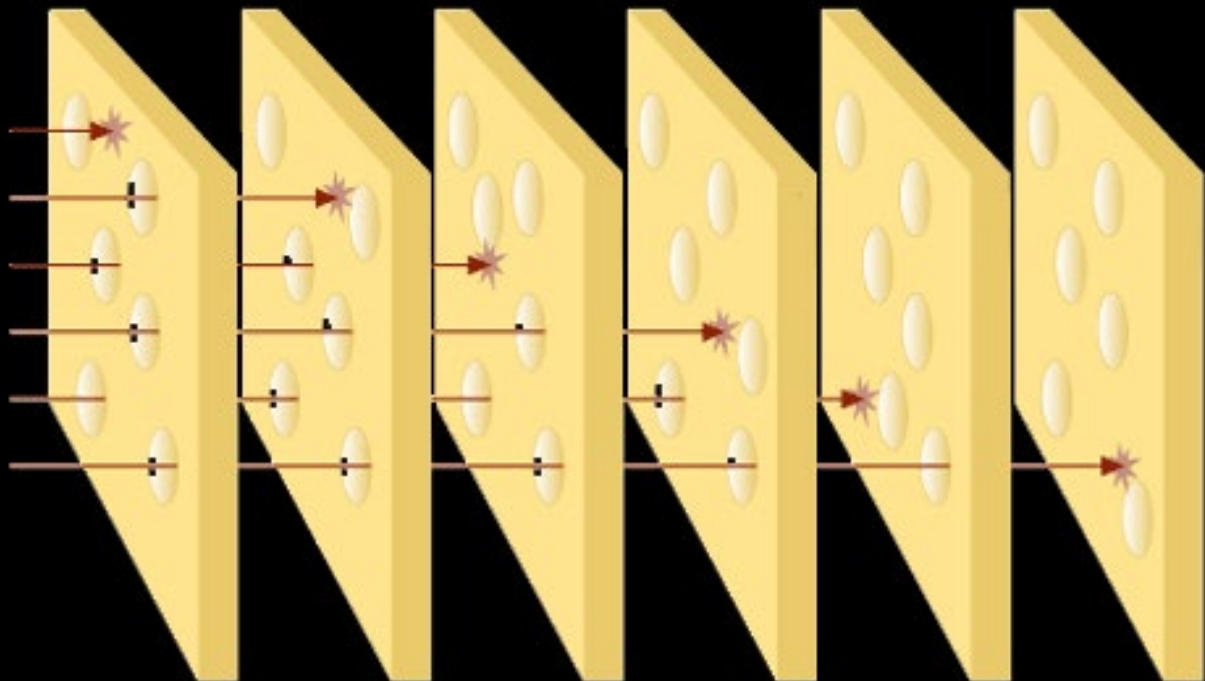
epigenetics

development

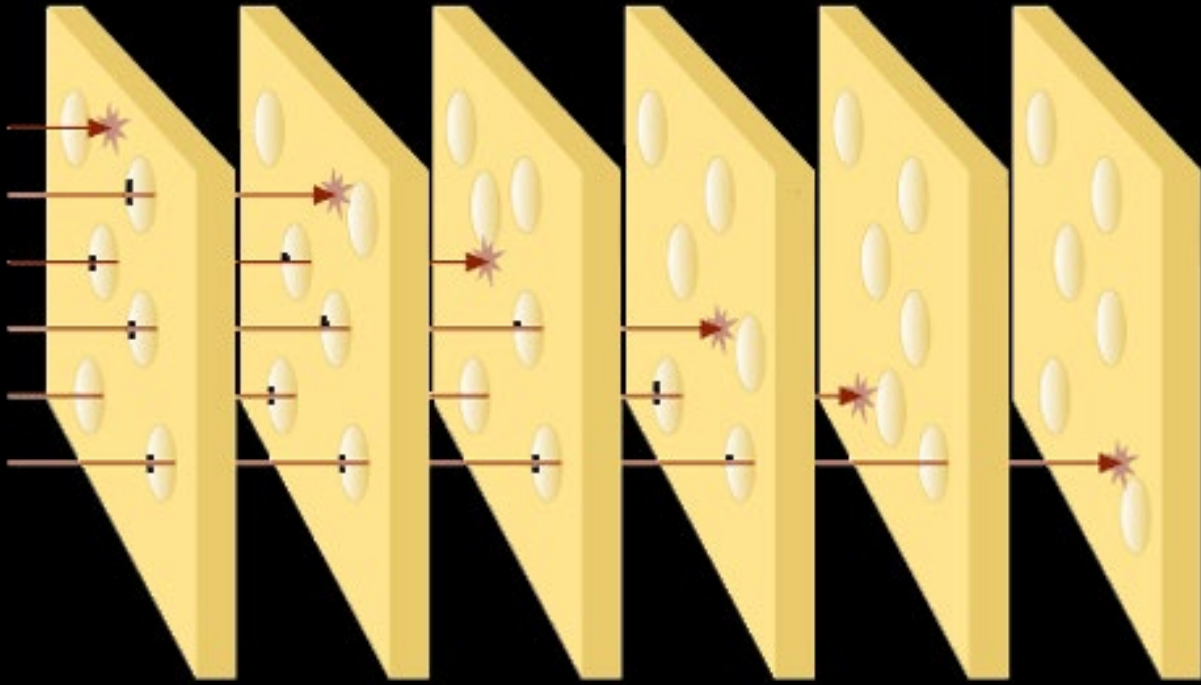
parental style

education

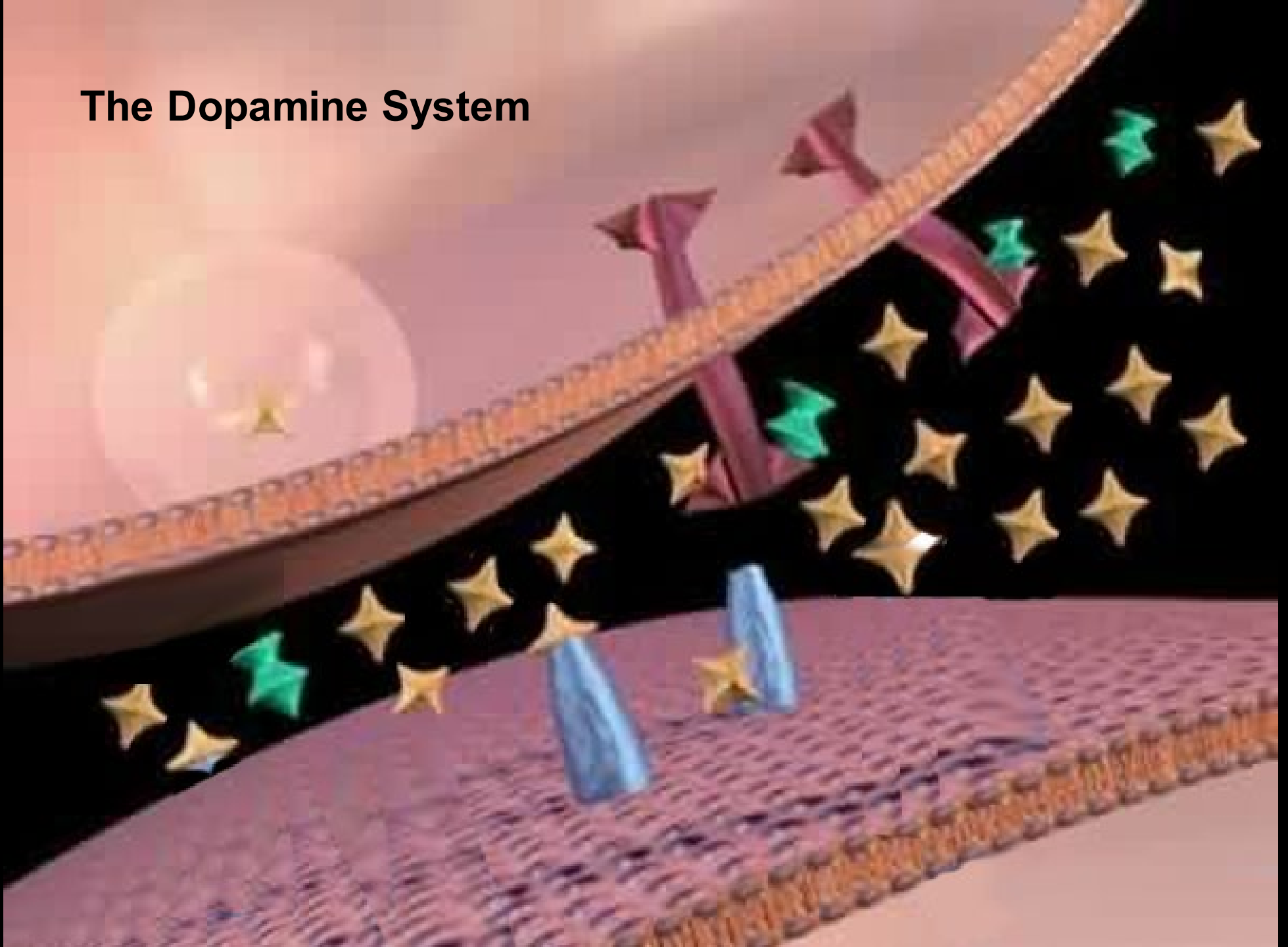
environment

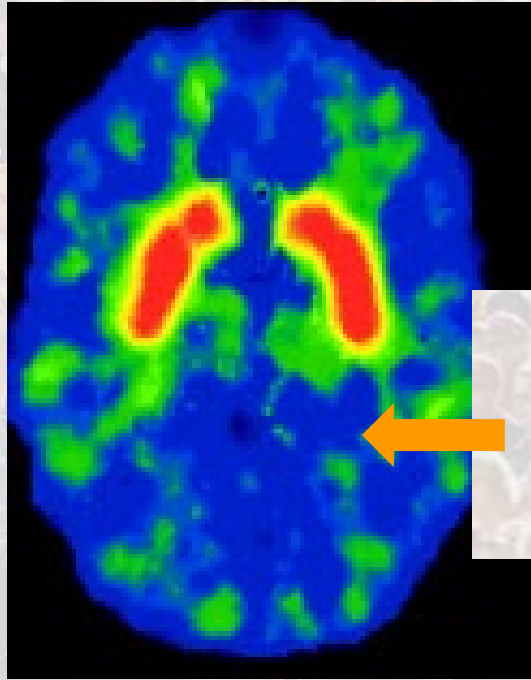


genetics



The Dopamine System

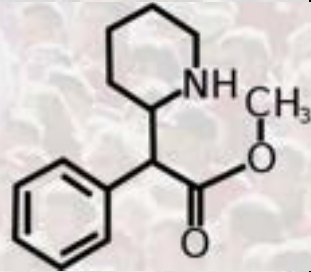




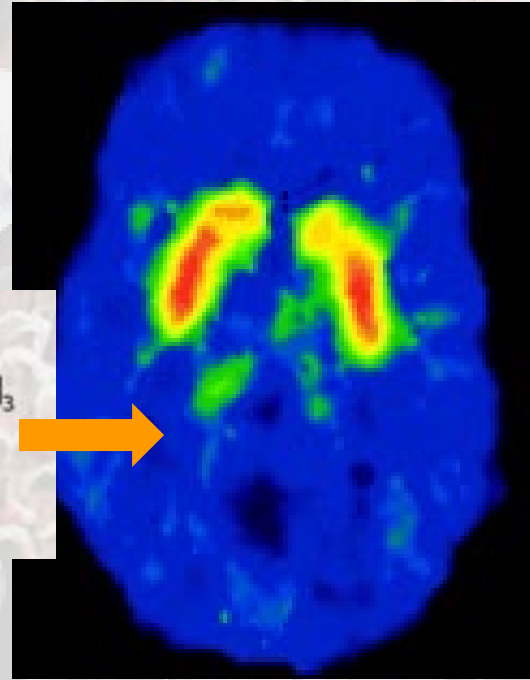
High Dopamine Receptor



Aversive



Ritalin

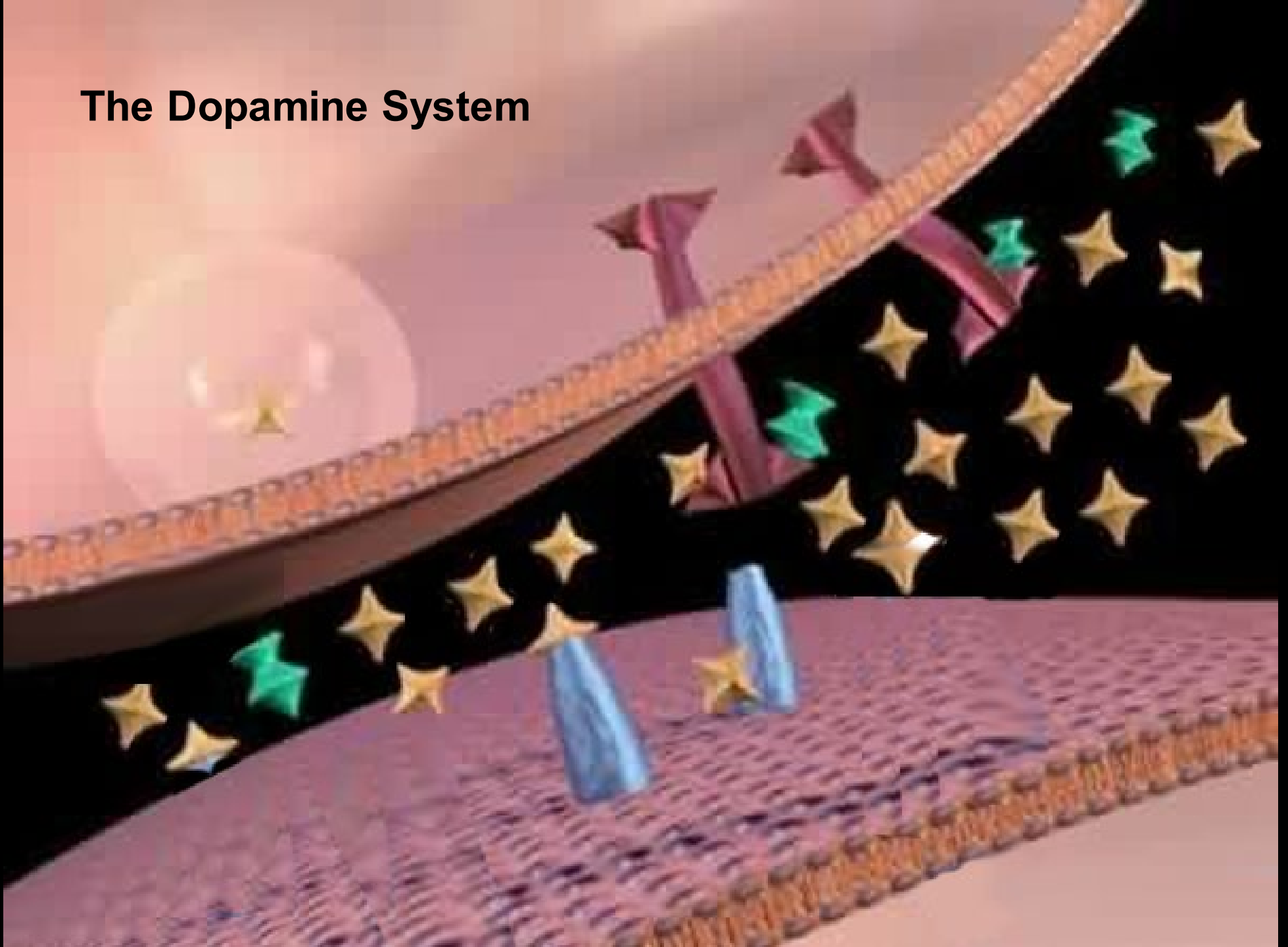


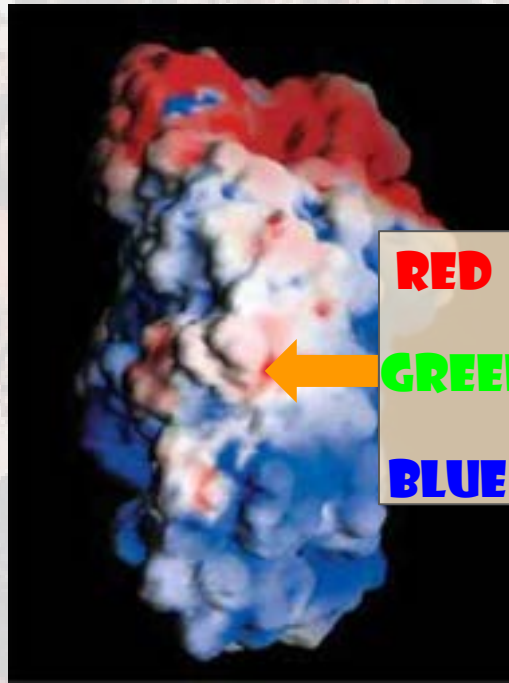
Low Dopamine Receptor



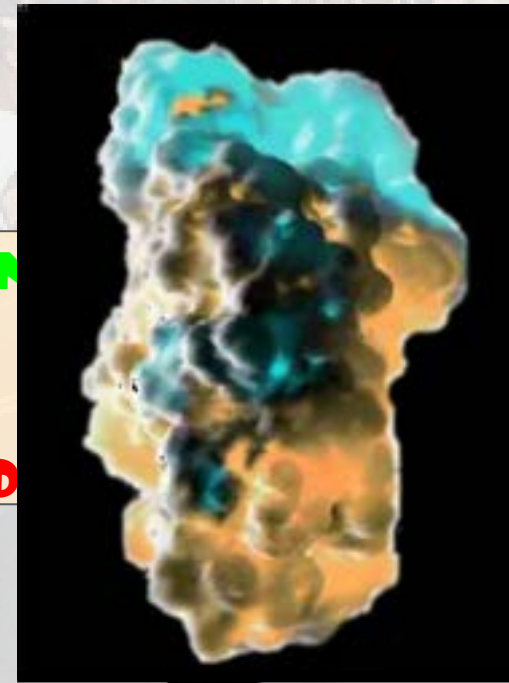
Pleasurable

The Dopamine System





RED	BLUE	GREEN
GREEN	RED	BLUE
BLUE	GREEN	RED



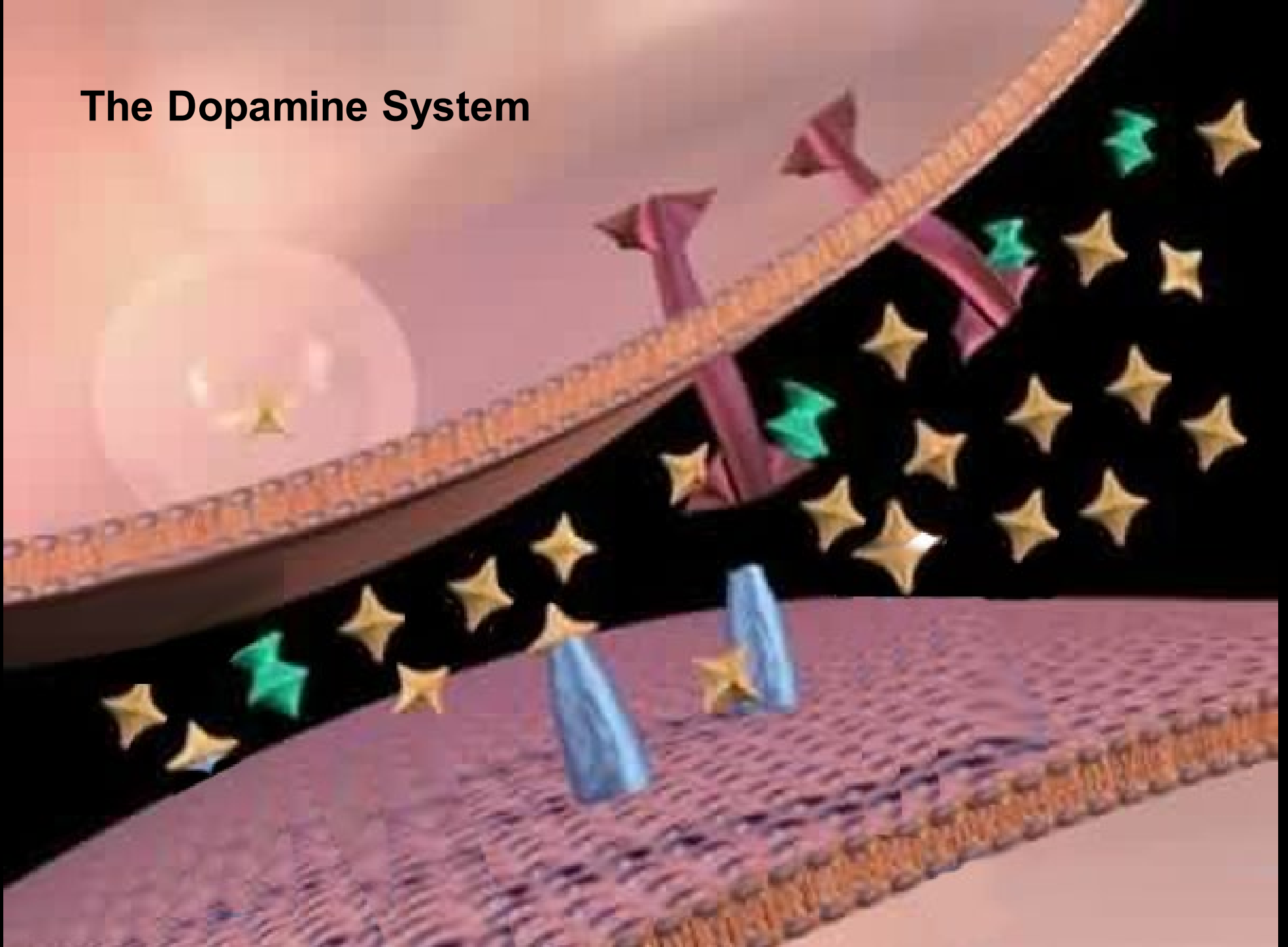
**Dopamine Transporter
GG**

**Dopamine Transporter
TT**

↓
**Good
Impulse Control**

↓
**Poor
Impulse Control**

The Dopamine System



(drug liking)

Dopamine Receptor

HIGH

LOW



(impulsivity)
Dopamine Transporter
TT GG



(drug liking)

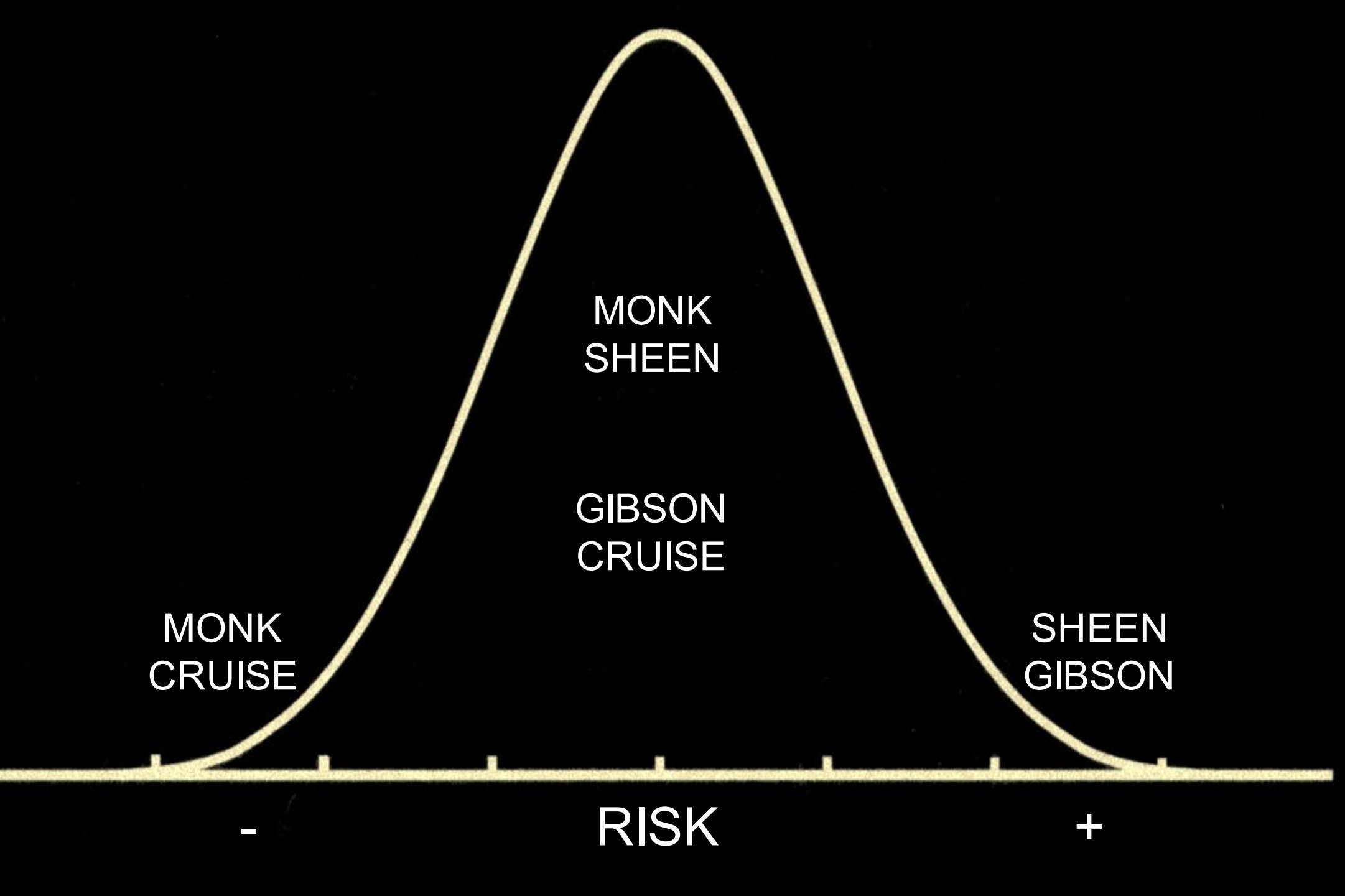
Dopamine Receptor

HIGH

LOW

(impulsivity)
Dopamine Transporter
TT GG





MONK
CRUISE

MONK
SHEEN

GIBSON
CRUISE

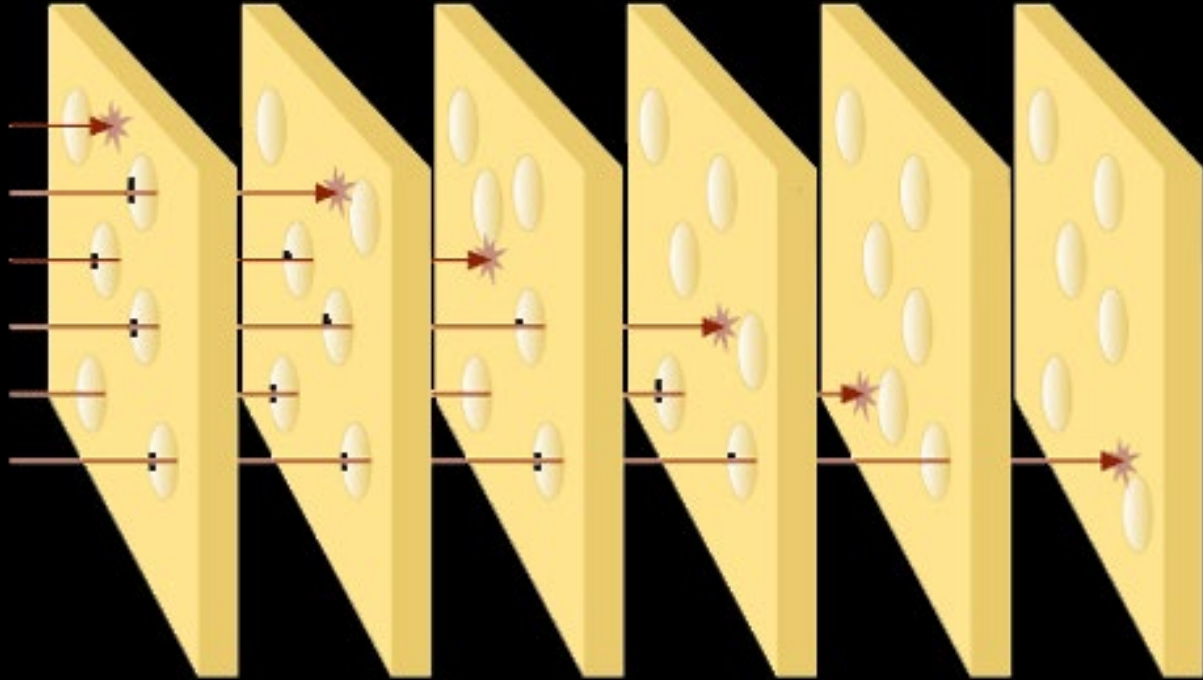
SHEEN
GIBSON

RISK

-

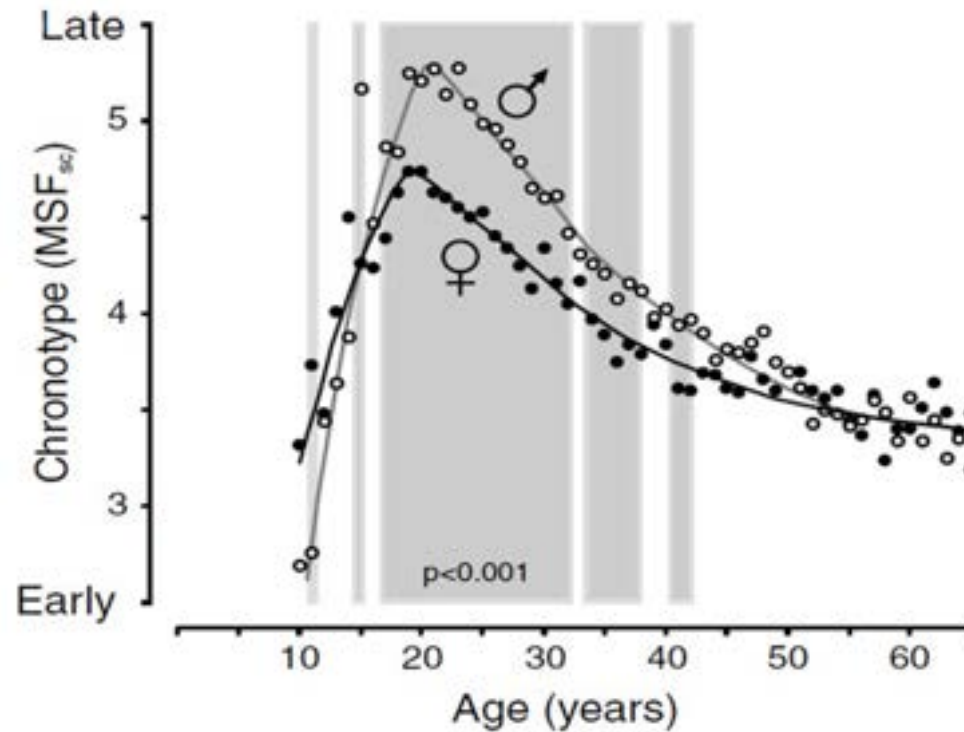
+

environment





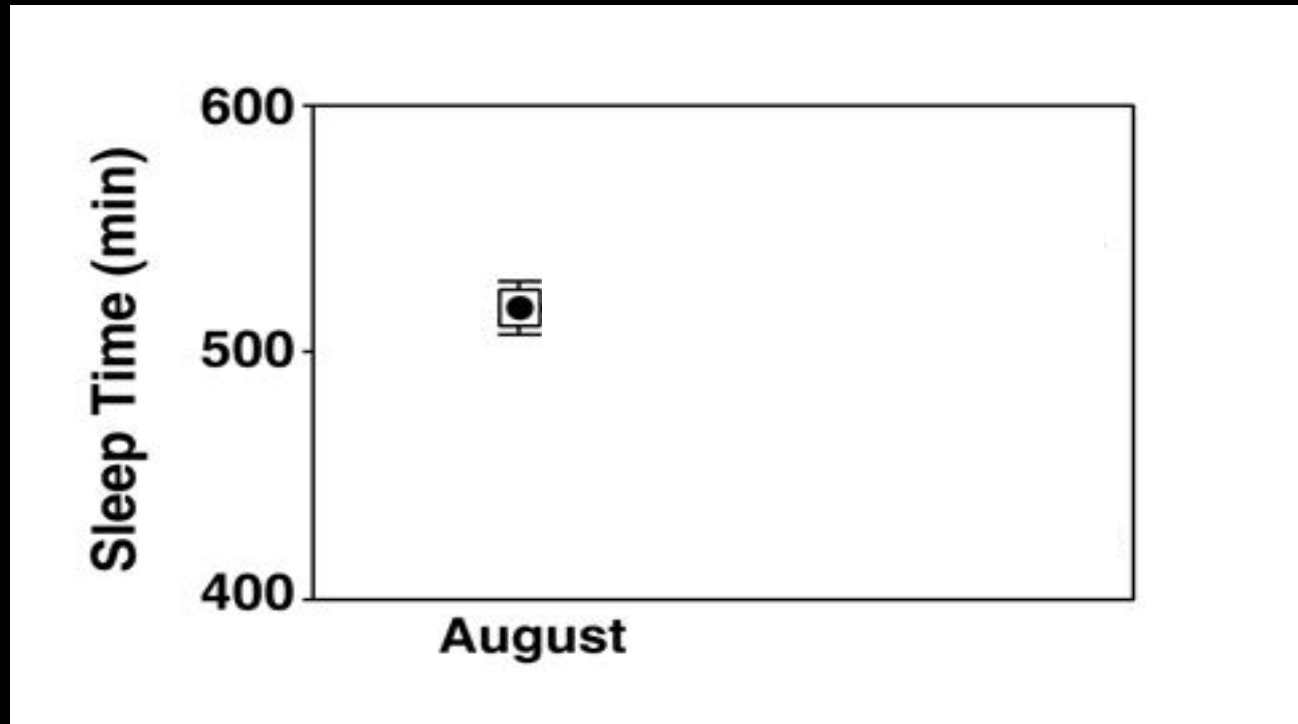
Sleep pattern changes as you grow older



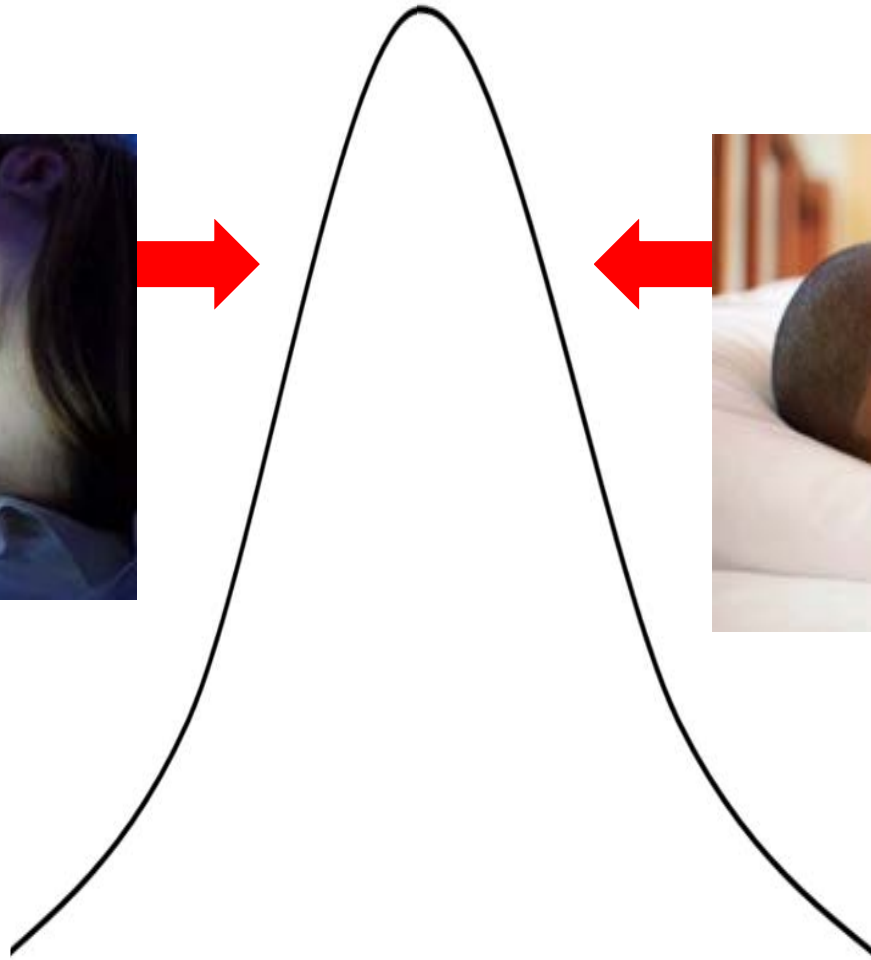
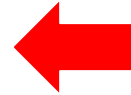
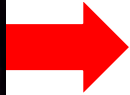
7 8 9 10 11 12 1 2 3 4 5 6 7 8



Current High School Start Times Contribute to Sleep Deprivation Among Adolescents.



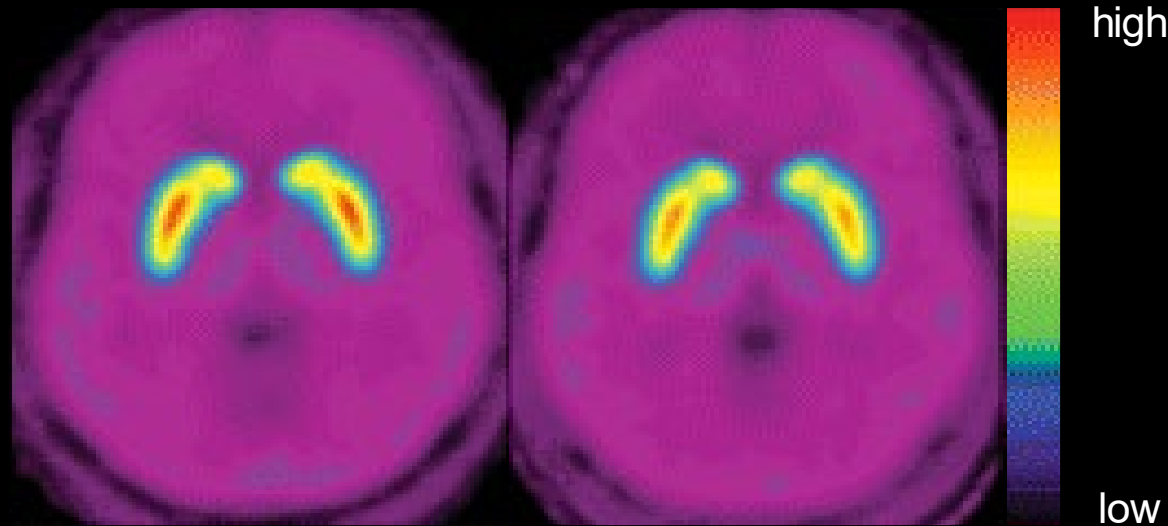




9 hours 6 hours

Effect of Sleep Deprivation on Dopamine Receptor Availability

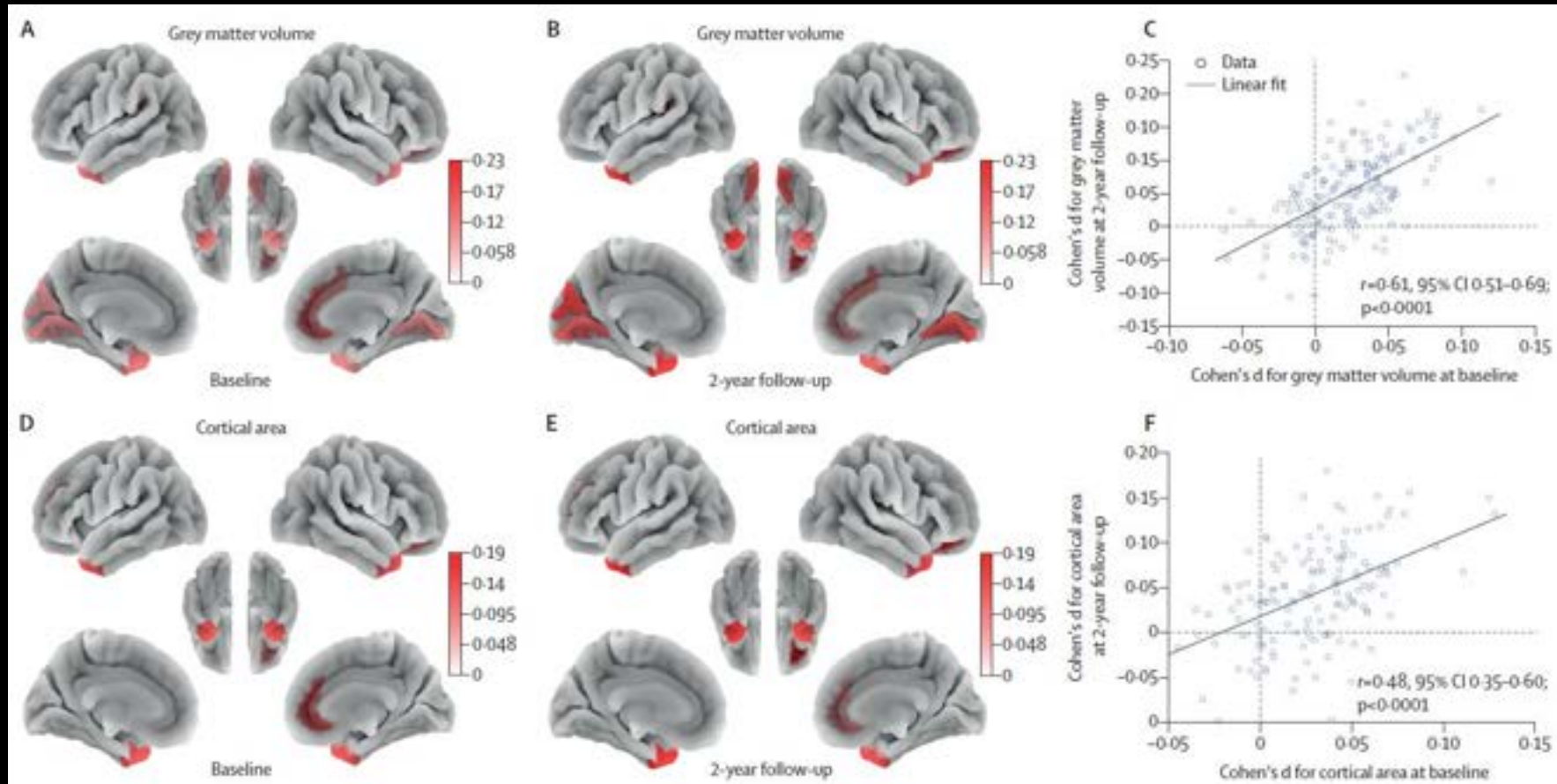
[¹¹C]raclopride



Non-Sleep
Deprived

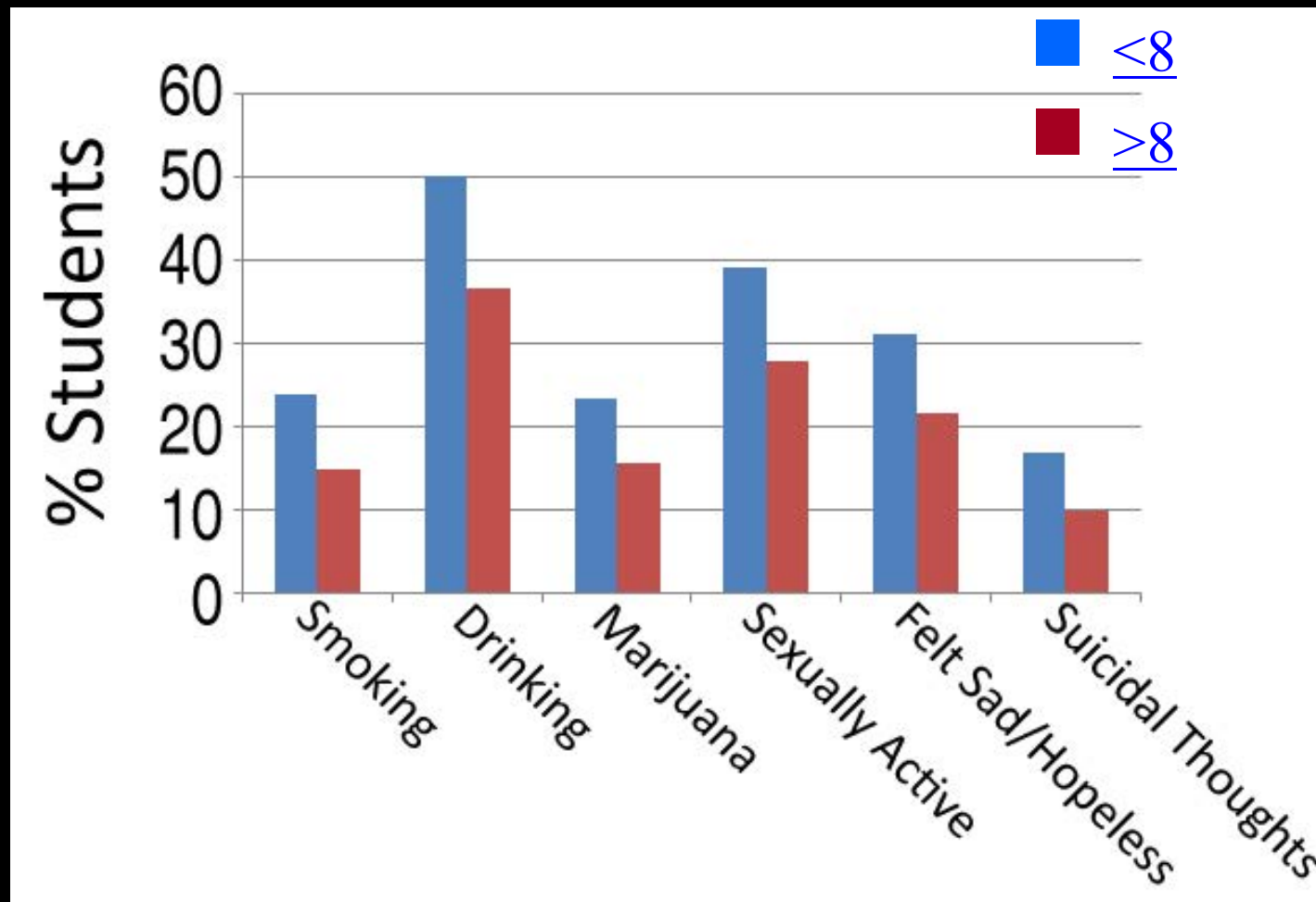
Sleep
Deprived

Long-lasting effect of insufficient sleep on neurocognitive development in early adolescence (longitudinal ABCD study)

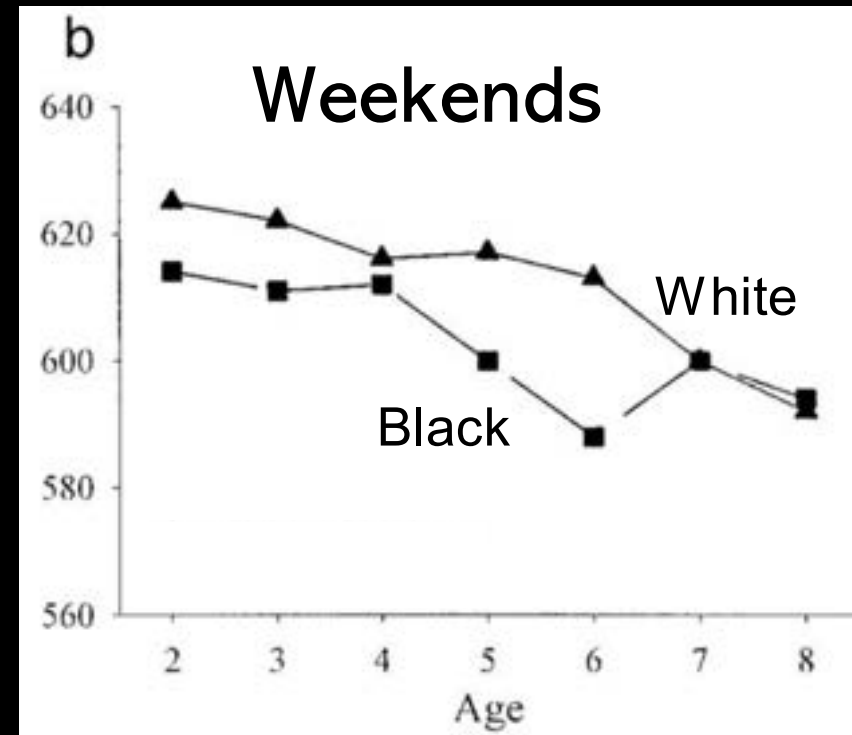
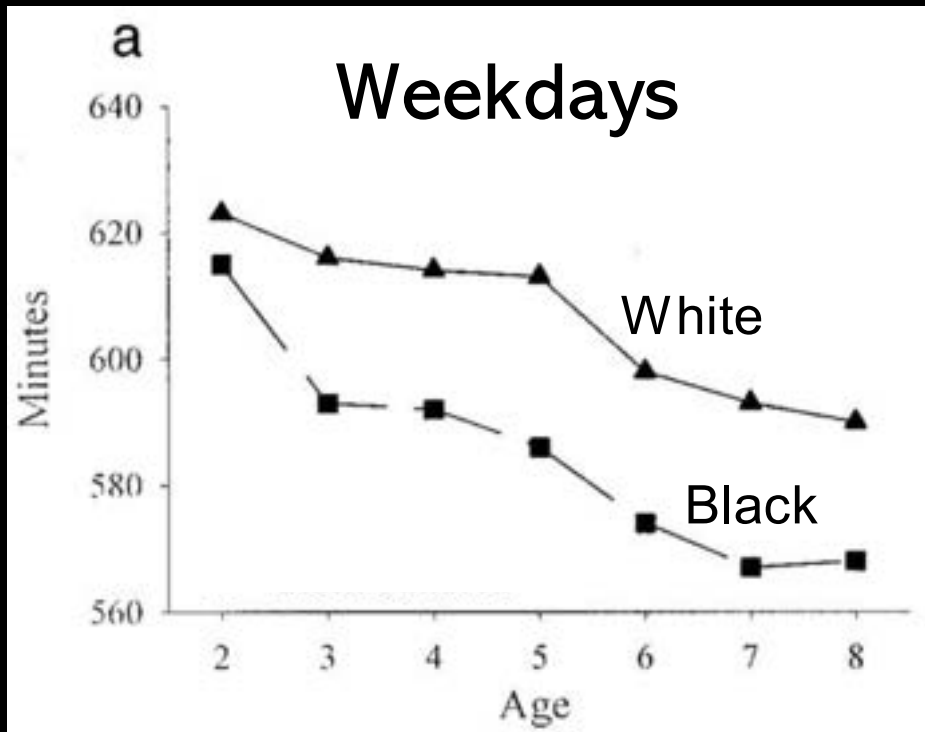


Insufficient sleep can modulate brain development profiles, leading to compromised cognitive functions and more behavioral problems in early adolescents.

Self-Reported Hours of Sleep and Selected Health-Risk Behaviors



Racial Disparities in Nocturnal Sleep Duration (2-8 year-old children)

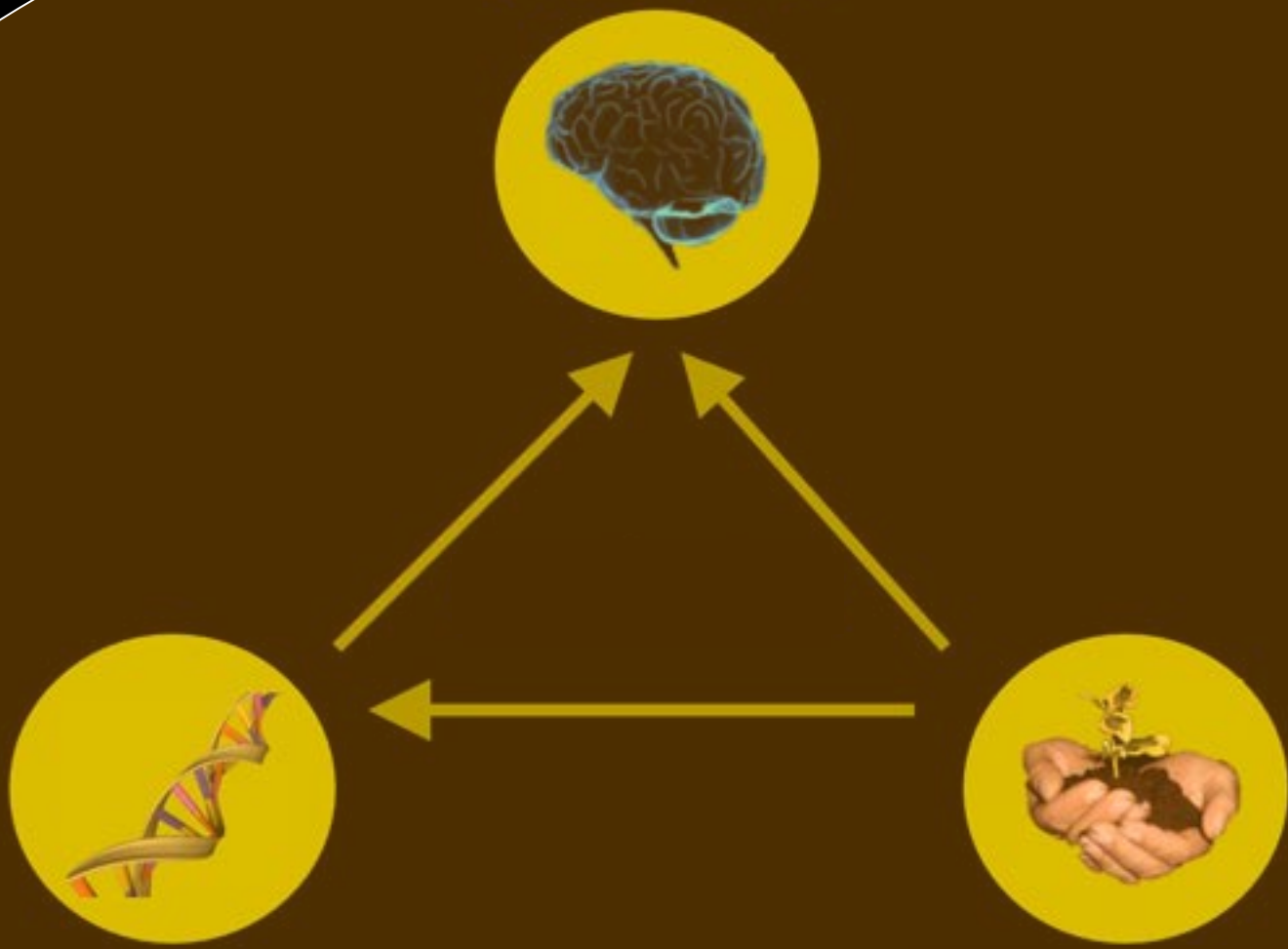


- The human brain
- The effect of addictive drugs
- Interindividual differences in risk
- **Boosting resilience**

What is the Overarching Neuroscientific Lesson for Promoting Mental Health and Increased Resilience?

I gave you some **information**
that I believe enlightening.

Evolution





The brain can fail

Design errors

Manufacturing errors

Extreme conditions





Prevention strategies

Evolutionary mismatch

We must be smarter about how we design our environments

Evolutionary mismatch







Prevention strategies

Evolutionary mismatch

We must be smarter about how we design our environments

Developmental errors

We have to be far more serious, careful and committed when it comes to protecting our kids' developing brains. Use the science.

Developmental errors





Prevention strategies

Evolutionary mismatch

We must be smarter about how we design our environments

Developmental errors

We have to be far more serious, careful and committed when it comes to protecting our kids' developing brains. Use the science.

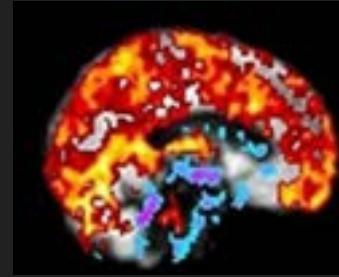
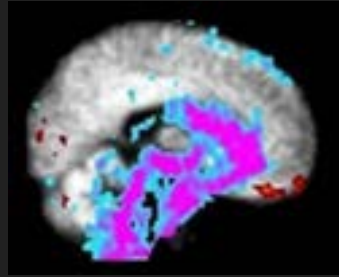
Overwhelming events

We must understand that our brains are Robust yet fragile; and educate ourselves and our kids accordingly to be more aware of our strengths and vulnerabilities.

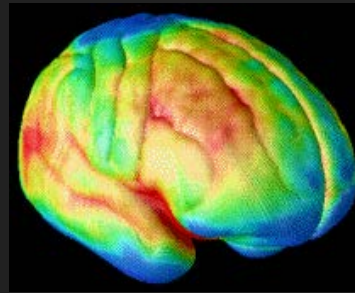
Neuroscience education in the XXI century



1



2



3



4





Alta Gracia

CORDOBA

ENTRE RIOS

Uruguay

Mendoza

Villa de Merlos

Rosario

San Luis

Río Cuarto

Venado Tuerto

SAN LUIS PROVINCE

MENDOZA PROVINCE

BUENOS AIRES

Montevideo

Argentina

General Pico

Trenque Lauquen

Santa Rosa

Coronel Suárez

BUENOS AIRES PROVINCE

LA PAMPA

Mar del Plata

NEUQUEN

Neuquen

Río Colorado

Bahía Blanca

Monte Hermoso

General Roca

Choele Choel

Los 4 secretos de tu cerebro

JUEVES 8/6

1ER AÑO 8.35 HS

ORGANIZA 4TO CS. SOC.

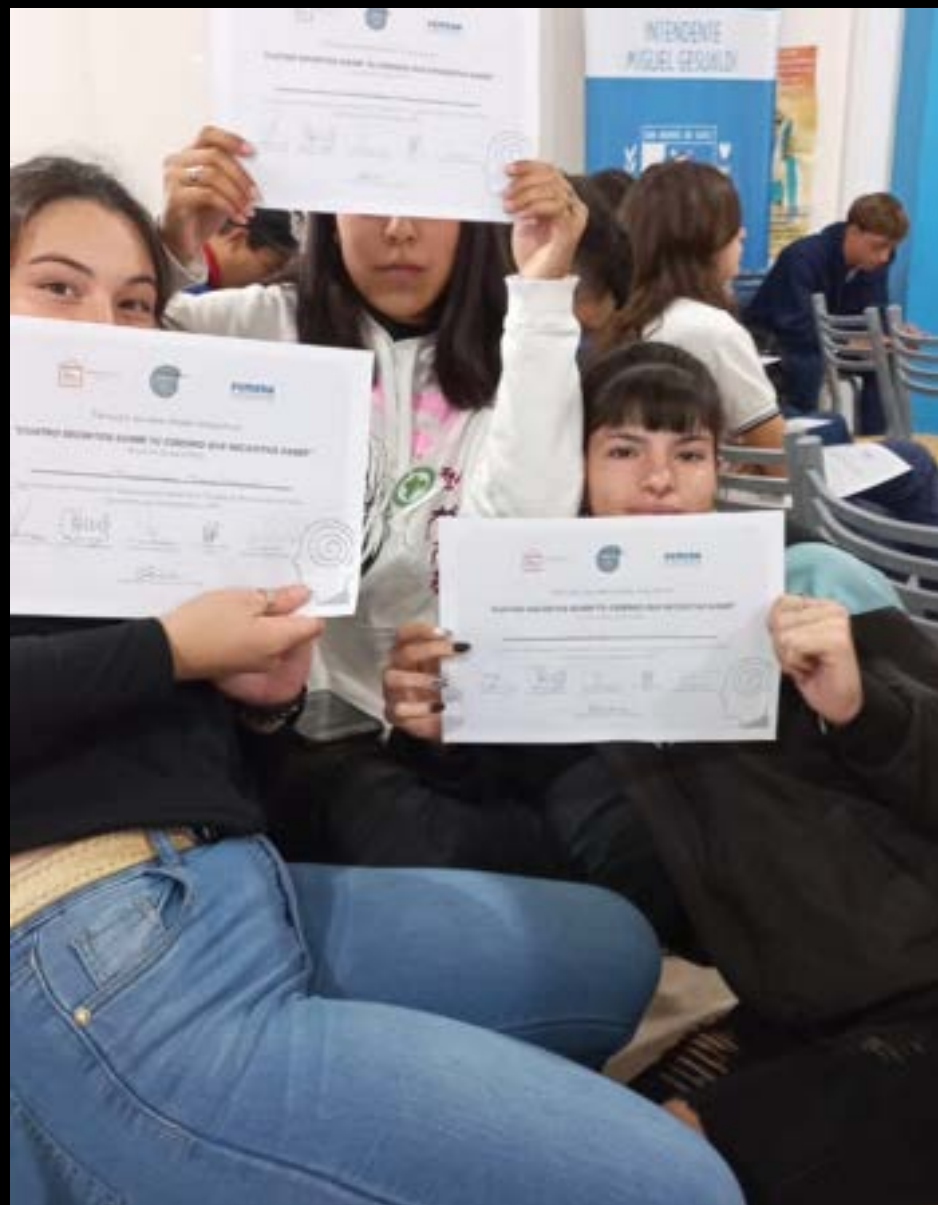
2DO AÑO 9.45 HS

CSNSL

3ER AÑO 10.55 HS





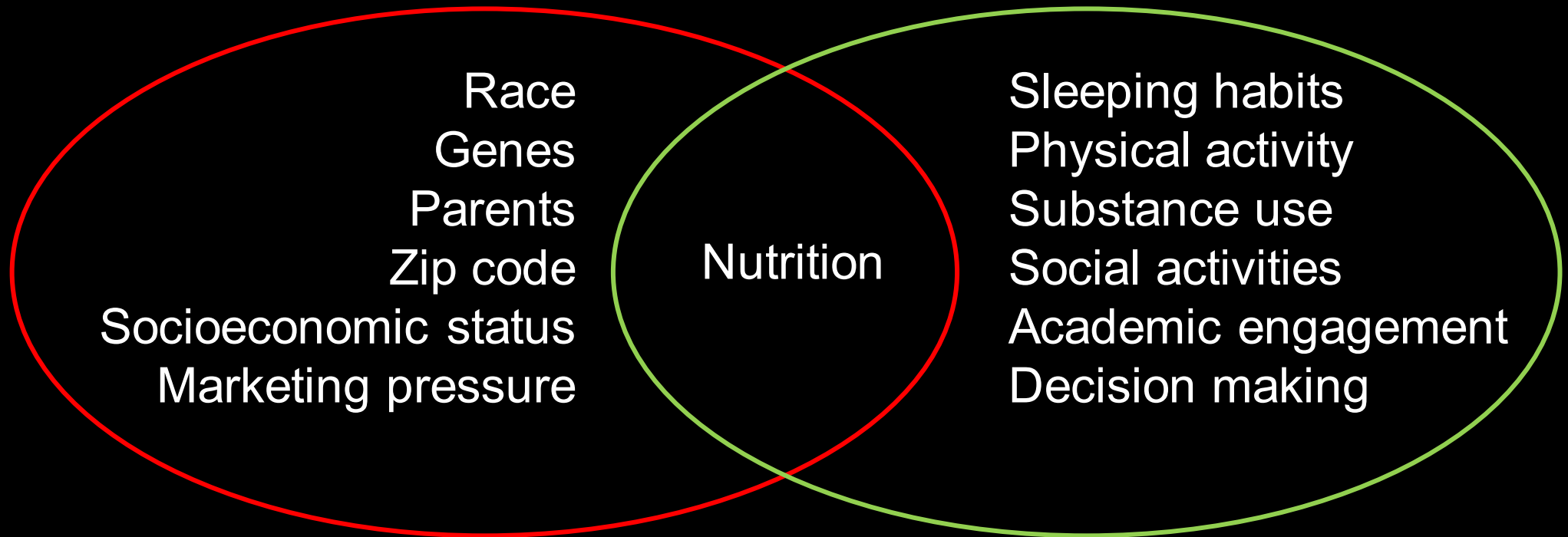


Some practical advice ...

Two type of factors affect our health and general well-being

Can't control

Can control



Race

Genes

Parents

Zip code

Socioeconomic status

Marketing pressure

Nutrition

Sleeping habits

Physical activity

Substance use

Social activities

Academic engagement

Decision making

Work with your kids and engage them to create social media free and brain expanding moments

Once a week, make some popcorn and have a screen night together

- Watch a good movie; expose them to new ideas, philosophical issues, and real lives that are worth exploring
 - Examples: Paterson (with Adam Driver)
Kurt Vonnegut: Unstuck in Time (by Robert B. Weide)
- Learn together about the brain and the impact that small decisions can have on our well being
 - Examples: Short NIDA YouTube video on Brain Development
TED talk: “Creativity as a life skill” by Gerard Puccio
TED talk: “Do schools kill creativity?” by Ken Robinson
TED talk: “Steal Like An Artist” by Austin Kleon
- Pick a funny movie and laugh together
 - Example: Death at a funeral
- Explore the work of renown directors:
 - Examples: Wes Anderson (Moonrise Kingdom, The Grand Budapest Hotel)
Guillermo del Toro (The shape of water)

Thank you

balerr@mail.nih.gov