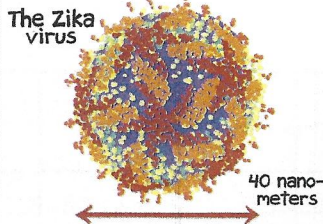


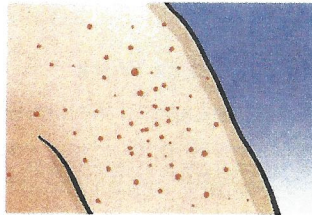
# THE ZIKA VIRUS

BY DWAYNE GODWIN  
& JORGE CHAM

THE ZIKA VIRUS WAS FIRST DETECTED IN MONKEYS IN THE ZIKA FOREST OF UGANDA IN 1947.



IT WAS INITIALLY CONSIDERED BENIGN. INFECTION IN HUMANS WAS RARE AND ONLY APPEARED TO CAUSE A MILD RASH AND FEVER.



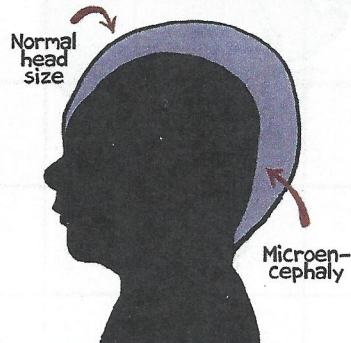
DURING OUTBREAKS IN 2007 AND 2013 IN THE PACIFIC, HEALTH OFFICIALS BEGAN TO SEE A LINK TO CERTAIN NEUROLOGICAL CONDITIONS IN HUMAN PATIENTS.



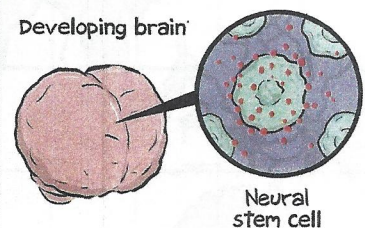
BY 2015 THE DISEASE HAD SPREAD THROUGHOUT ASIA AND SOUTH AMERICA AND IS NOW LINKED TO CASES OF INFANT MICROENCEPHALY.



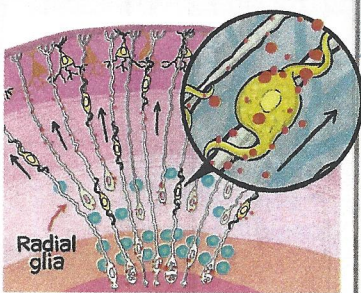
CHILDREN BORN WITH MICROENCEPHALY HAVE A MUCH SMALLER BRAIN AND HEAD. THEY MAY EXPERIENCE SEVERE INTELLECTUAL DISABILITY, SEIZURES AND EVEN DEATH.



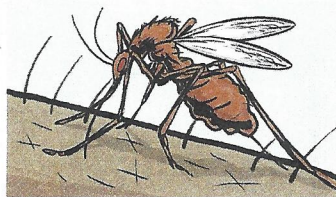
SCIENTISTS BELIEVE THE VIRUS TARGETS A PARTICULAR PROTEIN CALLED AXL, WHICH IS PREVALENT ON THE SURFACE OF NEURAL STEM CELLS.



THE VIRUS KILLS THESE CELLS, AS WELL AS RADIAL GLIAL CELLS, WHICH HELP DEVELOPING NEURONS MIGRATE TO THE OUTER LAYERS OF THE BRAIN.



ZIKA INFECTS 1 IN 5 PEOPLE EXPOSED TO THE VIRUS AND CAN BE TRANSMITTED BY MOSQUITOES, BLOOD TRANSFUSIONS, SEXUAL CONTACT OR FROM MOTHERS TO THEIR FETUSES.



HEALTH OFFICIALS ARE URGING RESIDENTS AND TRAVELERS IN ZIKA-PRONE AREAS TO TAKE SPECIAL PRECAUTIONS.

BECAUSE THE BEST WAY TO STOP THE SPREAD OF A VIRUS ...



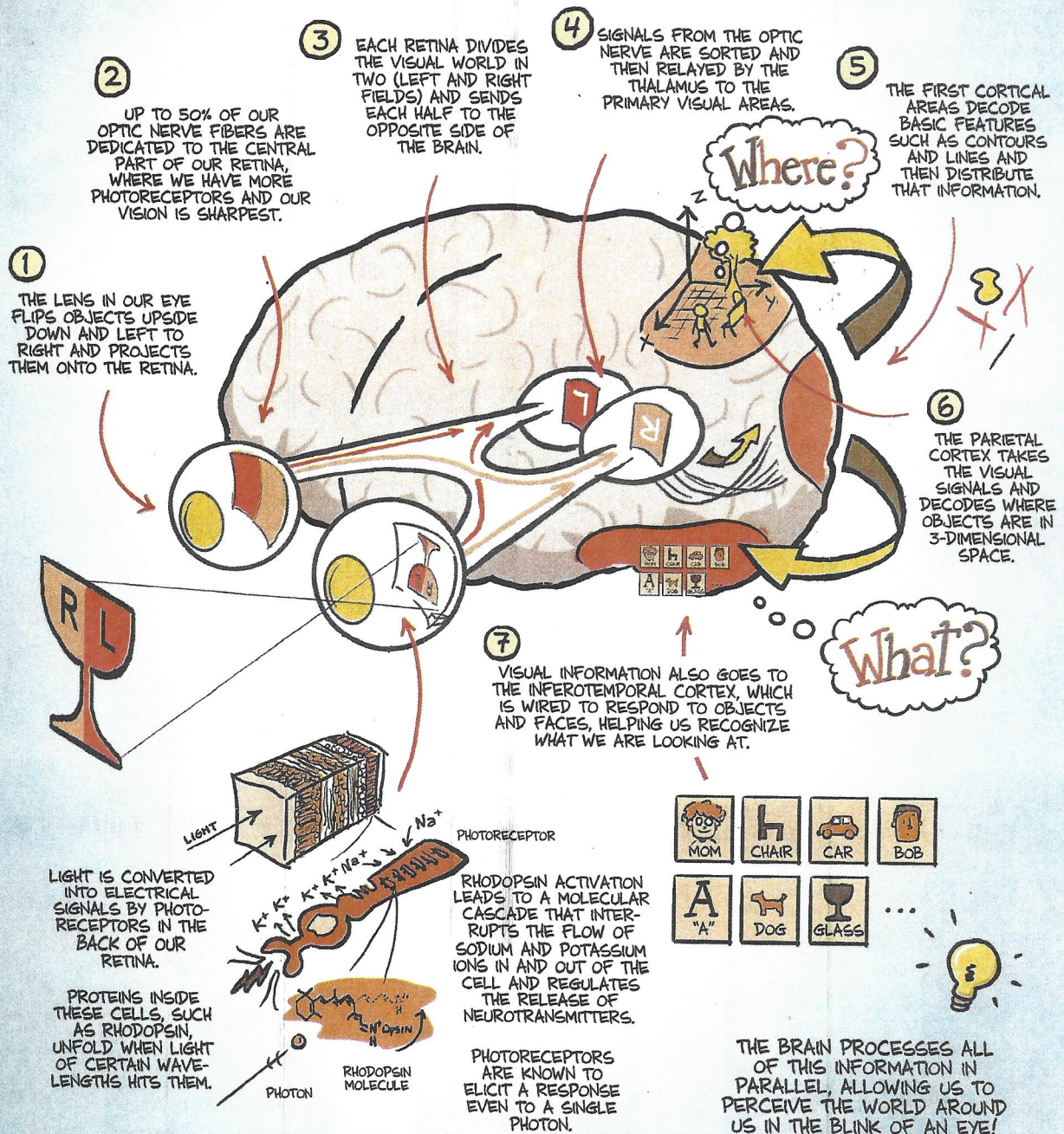
... IS FOR OUR KNOWLEDGE OF IT TO SPREAD EVEN FASTER.

● Dwayne Godwin is a neuroscientist at the Wake Forest University School of Medicine.  
Jorge Cham draws the comic strip *Piled Higher and Deeper* at [www.phdcomics.com](http://www.phdcomics.com)

BY DWAYNE GODWIN AND JORGE CHAM

# WHAT YOU SEE IS WHAT YOU GET?

How the brain splits up what your eyes capture

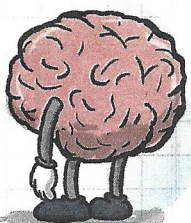


Dwayne Godwin is a neuroscientist at the Wake Forest University School of Medicine. Jorge Cham draws the comic strip *Piled Higher and Deeper* at [www.phdcomics.com](http://www.phdcomics.com)

# MIND IN MOTION

BY DWAYNE GODWIN  
& JORGE CHAM

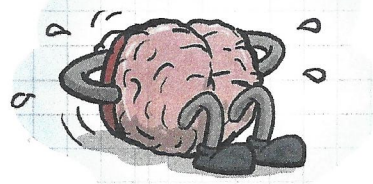
WANT TO GET YOUR  
BRAIN IN SHAPE?



THERE IS ONE SURE WAY TO  
IMPROVE YOUR MENTAL FITNESS:  
MOVE!



AEROBIC EXERCISE HAS BEEN  
SHOWN TO REDUCE THE RISK OF  
VASCULAR DEMENTIA, A CONDITION  
CAUSED BY PROBLEMS IN YOUR  
BRAIN'S BLOOD VESSELS.



EXERCISE IS ALSO BENEFICIAL  
AT THE MOLECULAR LEVEL:

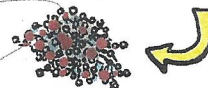
EXERCISE STIMULATES  
THE RELEASE OF GROWTH  
HORMONE (GH) FROM  
YOUR PITUITARY GLAND.



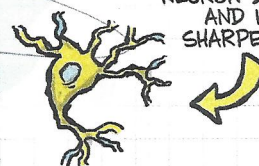
GH IN TURN STIMULATES  
PRODUCTION OF THE  
PROTEIN IGF-1, PRIMARILY  
IN THE LIVER.



IGF-1, WHICH NORMALLY  
TARGETS MUSCLE FOR  
GROWTH, CROSSES INTO  
YOUR BRAIN, WHERE IT  
INCREASES PRODUCTION OF  
BDNF, ANOTHER PROTEIN.



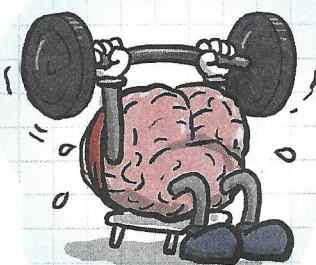
BDNF IS A NEUROTROPHIC  
PROTEIN THAT SUPPORTS  
NEURON DEVELOPMENT  
AND HELPS TO SHARPEN MEMORY.



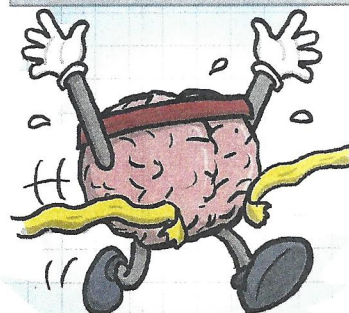
WHEN YOU WORK OUT, YOUR  
ANTERIOR PITUITARY RELEASES  
ENDORPHINS, THE BRAIN'S  
NATURAL PAINKILLERS, WHICH IS  
WHY MANY PEOPLE REPORT A  
"HIGH" WHEN THEY EXERCISE.



DESPITE EVIDENCE THAT  
EXERCISE IMPROVES MOOD  
AND TEST SCORES, MANY  
SCHOOLS ARE CUTTING PHYSICAL  
EDUCATION PROGRAMS.



SO LET'S GET MOVING!



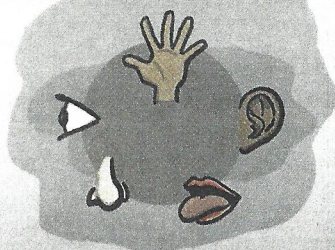
YOUR BODY (AND YOUR BRAIN)  
WILL THANK YOU FOR IT.

● **Dwayne Godwin** is a neuroscientist at the Wake Forest University School of Medicine.  
**Jorge Cham** draws the comic strip *Piled Higher and Deeper* at [www.phdcomics.com](http://www.phdcomics.com).

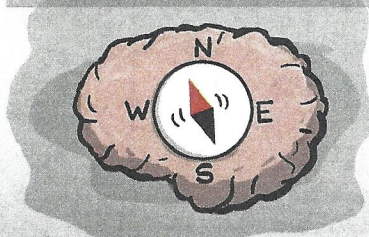
# Mental Compass

BY DWAYNE GODWIN  
& JORGE CHAM

THERE ARE FIVE COMMON  
BASIC SENSES:



BUT DID YOU KNOW THAT SOME  
BRAINS CAN SENSE MAGNETIC  
FIELDS, LIKE A COMPASS?



A VARIETY OF ANIMALS ARE  
ABLE TO NAVIGATE THE  
EARTH'S MAGNETIC FIELD TO  
AID THEM IN THEIR MIGRATION.

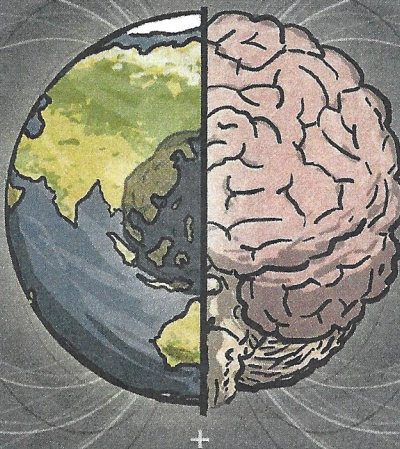


SOMEHOW THEIR BRAINS  
CAN DETECT THE SUBTLE  
MAGNETIC FIELD LINES  
CAUSED BY THE MOTION  
OF IRON IN THE EARTH'S  
MOLTEN OUTER CORE.

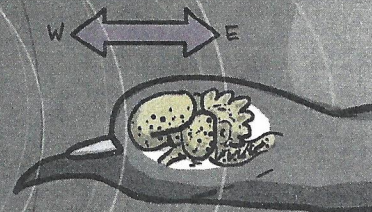


SCIENTISTS AREN'T SURE  
HOW THEY DO THIS, BUT THERE  
ARE SOME HYPOTHESES.

THE EARTH'S MAGNETIC  
NORTH POLE IS ACTUALLY  
A MAGNETIC SOUTH POLE.

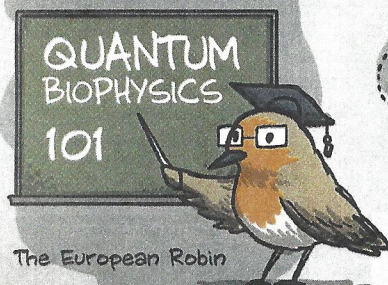


ONE HYPOTHESIS IS THAT THESE  
ANIMALS HAVE SPECIAL DEPOSITS  
OF LODESTONE, A MAGNETIZED  
OXIDE OF IRON, IN THEIR BODIES.



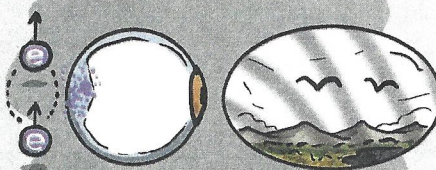
SPECIAL RECEPTORS IN THEIR  
NERVOUS SYSTEM THEN SENSE  
HOW THESE DEPOSITS REACT TO  
AN OUTSIDE MAGNETIC FIELD.

IN ONE ANIMAL, IT HAS BEEN  
HYPOTHEZIZED THAT  
QUANTUM ENTANGLEMENT  
PLAYS A KEY ROLE.



The European Robin

A PROTEIN CALLED CRYPTOCHROME  
IN THE EYE'S PHOTORECEPTORS  
GENERATES TWO COUPLED  
ELECTRONS WHEN LIGHT STRIKES IT.



MAGNETOVISION

THE ENTANGLED ELECTRONS' SPIN IS  
AFFECTED BY WEAK MAGNETIC FIELDS,  
WHICH MAY ALLOW THE ROBIN TO "SEE"  
THE SURROUNDING MAGNETIC FIELD LINES.

SO YOU COULD SAY THESE  
ANIMALS HAVE A GOOD HEAD  
FOR DIRECTIONS ...



... OR THAT THEY'RE LOADED  
WITH ANIMAL MAGNETISM.

● Dwayne Godwin is a neuroscientist at the Wake Forest University School of Medicine.  
Jorge Cham draws the comic strip *Piled Higher and Deeper* at [www.phdcomics.com](http://www.phdcomics.com)

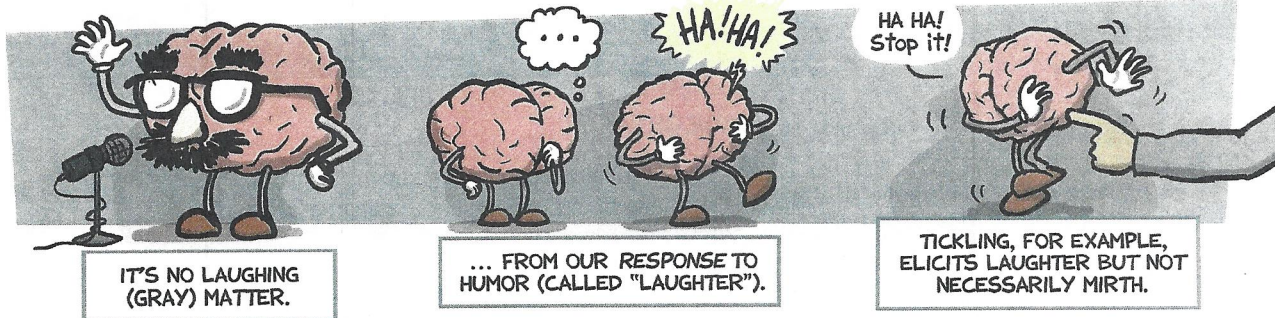
# The Brain's Funny Bone

BY DWAYNE GODWIN & JORGE CHAM

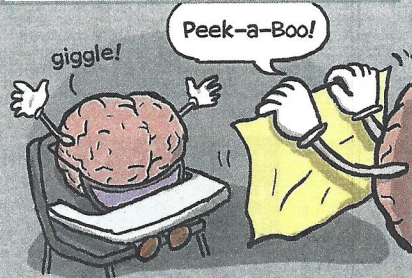
WHAT HAPPENS IN YOUR BRAIN WHEN YOU FIND SOMETHING FUNNY?

IN STUDIES, SCIENTISTS OFTEN SEPARATE OUR PERCEPTION OF HUMOR (CALLED "MIRTH") ...

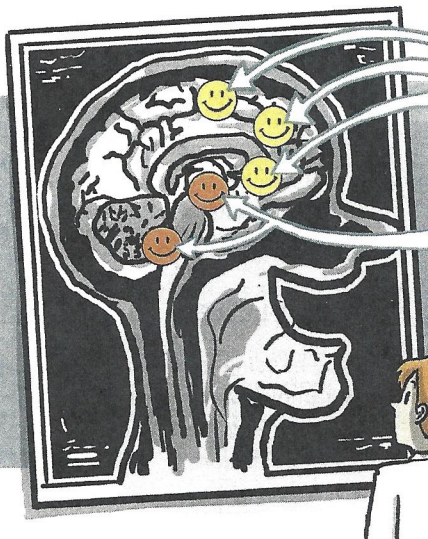
THESE TWO THINGS ARE ASSOCIATED WITH DIFFERENT AREAS OF THE BRAIN:



AREAS ASSOCIATED WITH THE PERCEPTION OF HUMOR ARE ALSO ASSOCIATED WITH THE PROCESSING OF INCONGRUITY, LIKE WHEN YOUR EXPECTATIONS ARE VIOLATED.



THIS RESPONSE HAS BEEN SHOWN TO CHANGE WITH AGE.



AREAS LIKE THE PREFRONTAL CORTEX, THE TEMPORAL LOBES AND THE SUPPLEMENTARY MOTOR AREA SEEM IMPORTANT FOR "GETTING" A JOKE ...

... WHILE DEEPER BRAIN AREAS, LIKE THE HYPOTHALAMUS AND PERIAQUEDUCTAL GRAY, APPEAR TO BE INVOLVED IN PRODUCING THE PHYSICAL REACTION OF LAUGHTER.

IT'S A PMRI: PUN-ctional Magnetic Resonance Image.

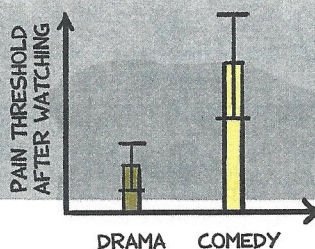
STUDIES HAVE FOUND THAT WATCHING FUNNY CARTOONS ACTIVATES THE BRAIN'S REWARD CENTERS, RELEASING DOPAMINE.

THE NEUROLOGICALLY FEEL-GOOD COMEDY OF THE YEAR!



WHICH IS WHY FEEL-GOOD COMEDIES, UM, FEEL GOOD.

LAUGHTER IS ALSO GOOD FOR YOU: IT'S BEEN SHOWN TO LOWER STRESS HORMONES AND MAY LEAD TO THE RELEASE OF ENDORPHINS, WHICH CAN INCREASE YOUR TOLERANCE TO PAIN.



SO HERE'S THE PUNCH LINE: DON'T JEST SIT THERE, YUK IT UP!



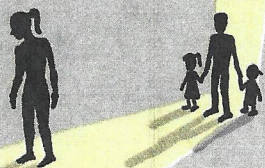
HUMOR AS MEDICINE IS NO JOKE.

● Dwayne Godwin is a neuroscientist at the Wake Forest University School of Medicine.  
Jorge Cham draws the comic strip *Piled Higher and Deeper* at [www.phdcomics.com](http://www.phdcomics.com)

# ADDICTION

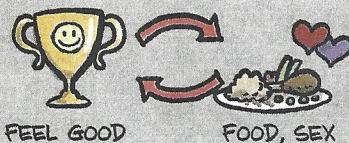
BY DWAYNE GODWIN  
& JORGE CHAM

ADDICTION COSTS AMERICANS MORE THAN \$700 BILLION A YEAR IN LOST WORK, TREATMENT AND DRUG-RELATED CRIME.



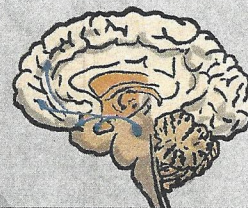
BUT WHAT IS ADDICTION... AND HOW DO WE BREAK IT?

ADDICTION HAS ITS ROOTS IN THE BRAIN'S REWARD SYSTEM.



IT'S THE SYSTEM MEANT TO REINFORCE BEHAVIORS NEEDED FOR SURVIVAL, SUCH AS EATING AND HAVING SEX.

ONE IMPORTANT COMPONENT IN THIS SYSTEM IS THE MESOLIMBIC PATHWAY...

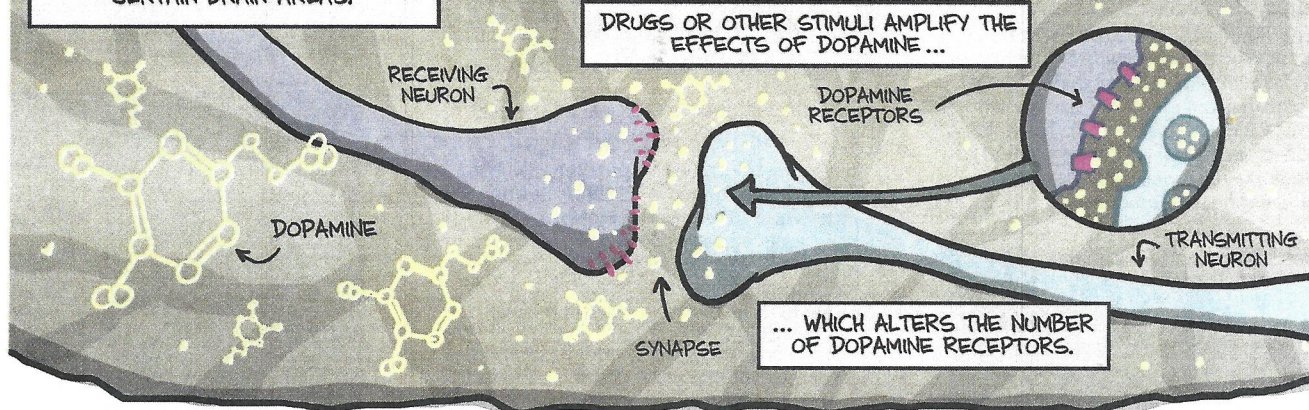


... A COLLECTION OF NEURONS THAT PRODUCES AND RELEASES DOPAMINE WHENEVER YOU ENGAGE IN REWARDING BEHAVIORS.

DOPAMINE IS A NEUROTRANSMITTER THAT, AMONG MANY OTHER THINGS, GIVES YOU THE SENSATION OF PLEASURE WHEN RELEASED IN CERTAIN BRAIN AREAS.

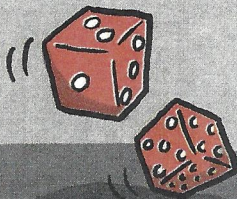
ADDICTION CAN OCCUR WHEN THIS PATHWAY IS HIJACKED REPEATEDLY BY DRUGS OR OTHER STIMULI, CREATING CHANGES IN THE SYNAPTIC CONNECTION THAT ARE HARD TO REVERSE.

DRUGS OR OTHER STIMULI AMPLIFY THE EFFECTS OF DOPAMINE...



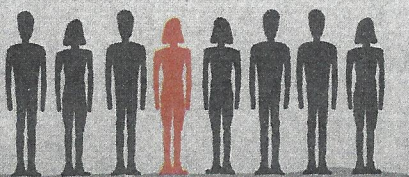
... WHICH ALTERS THE NUMBER OF DOPAMINE RECEPTORS.

THIS CHANGED PATHWAY, ALONG WITH INCREASED STRESS DURING WITHDRAWAL, DRIVES ADDICTS TO COMPULSIVELY SEEK OUT THE STIMULUS...



... DESPITE LONG-TERM NEGATIVE CONSEQUENCES.

NOT ALL DRUGS OR ADDICTS ARE THE SAME. SOME PEOPLE ARE GENETICALLY MORE SUSCEPTIBLE TO ADDICTION...



... AND A DRUG'S ADDICTIVENESS SEEMS TO DEPEND ON HOW RAPIDLY IT ACTS ON YOUR SYSTEM.

HEALING ADDICTION IS A DIFFICULT PROCESS, AIDED BY GROUP SUPPORT.



THE BEST WAY TO BEAT A HARMFUL DEPENDENCY IS BY DEPENDING ON OTHERS.

● Dwayne Godwin is a neuroscientist at the Wake Forest University School of Medicine.  
Jorge Cham draws the comic strip *Piled Higher and Deeper* at [www.phdcomics.com](http://www.phdcomics.com)