





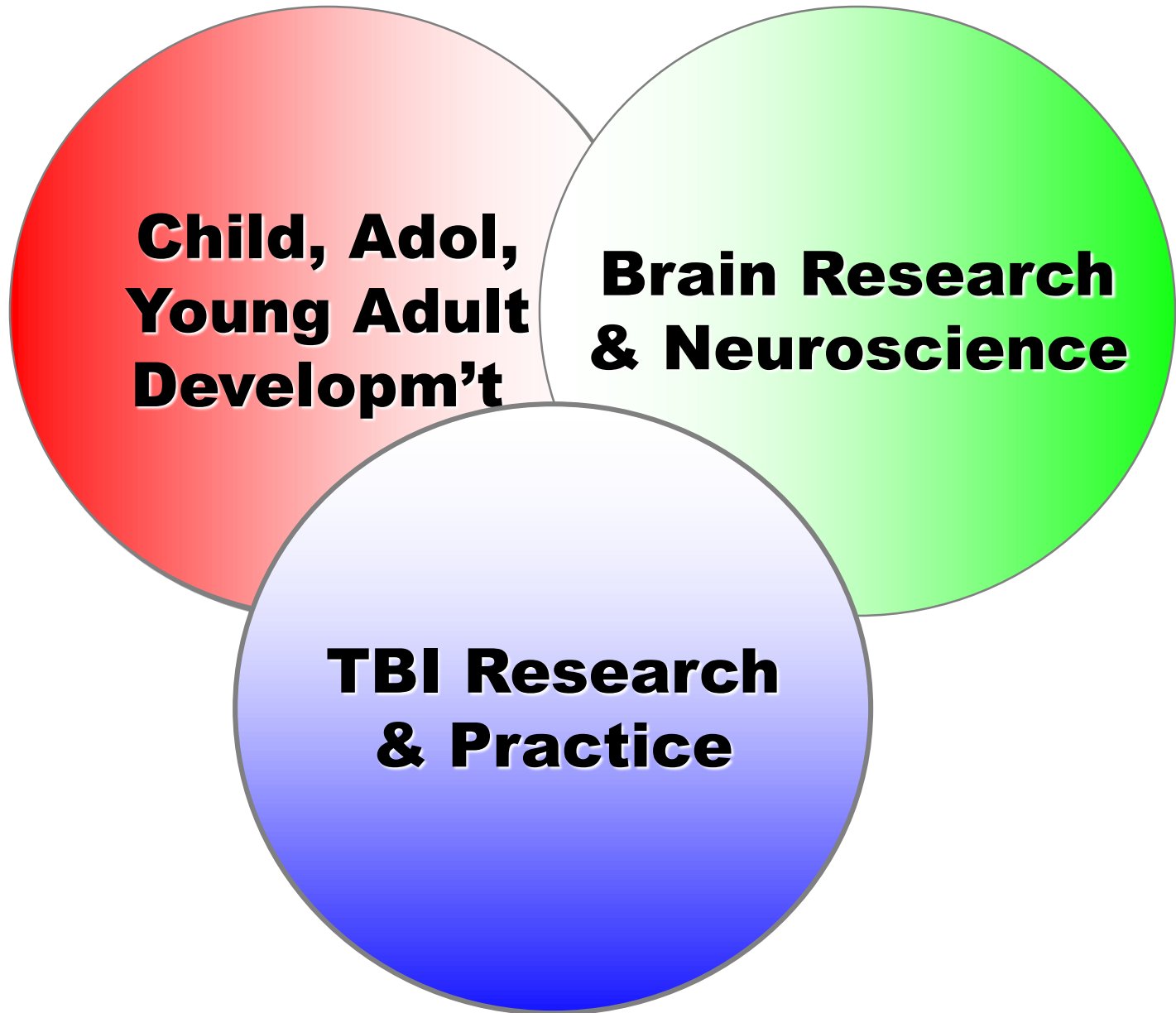
# **Neuro-Development after Brain Injury in Children, Youth & Young Adults: a chronic disease process**

**Ron Savage**

**The Sarah Jane Brain Foundation**

**International Pediatric Brain Injury Society**

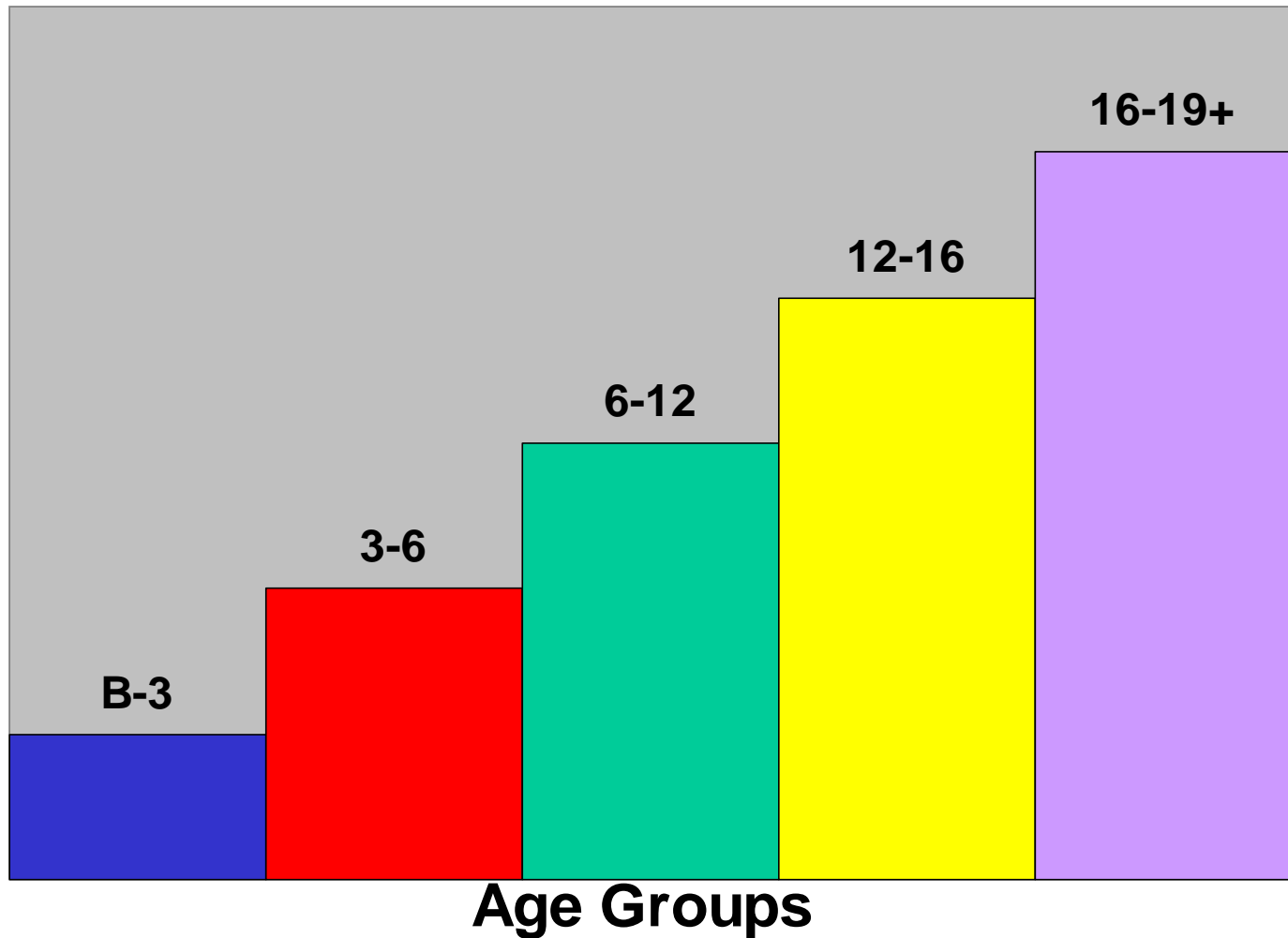




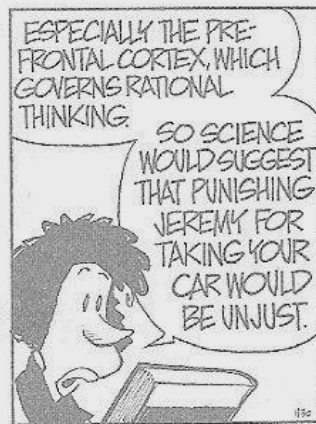
# #1. What do we know about Children, Adolescents and Young Adults?



# Peak Maturation Periods



# Zits



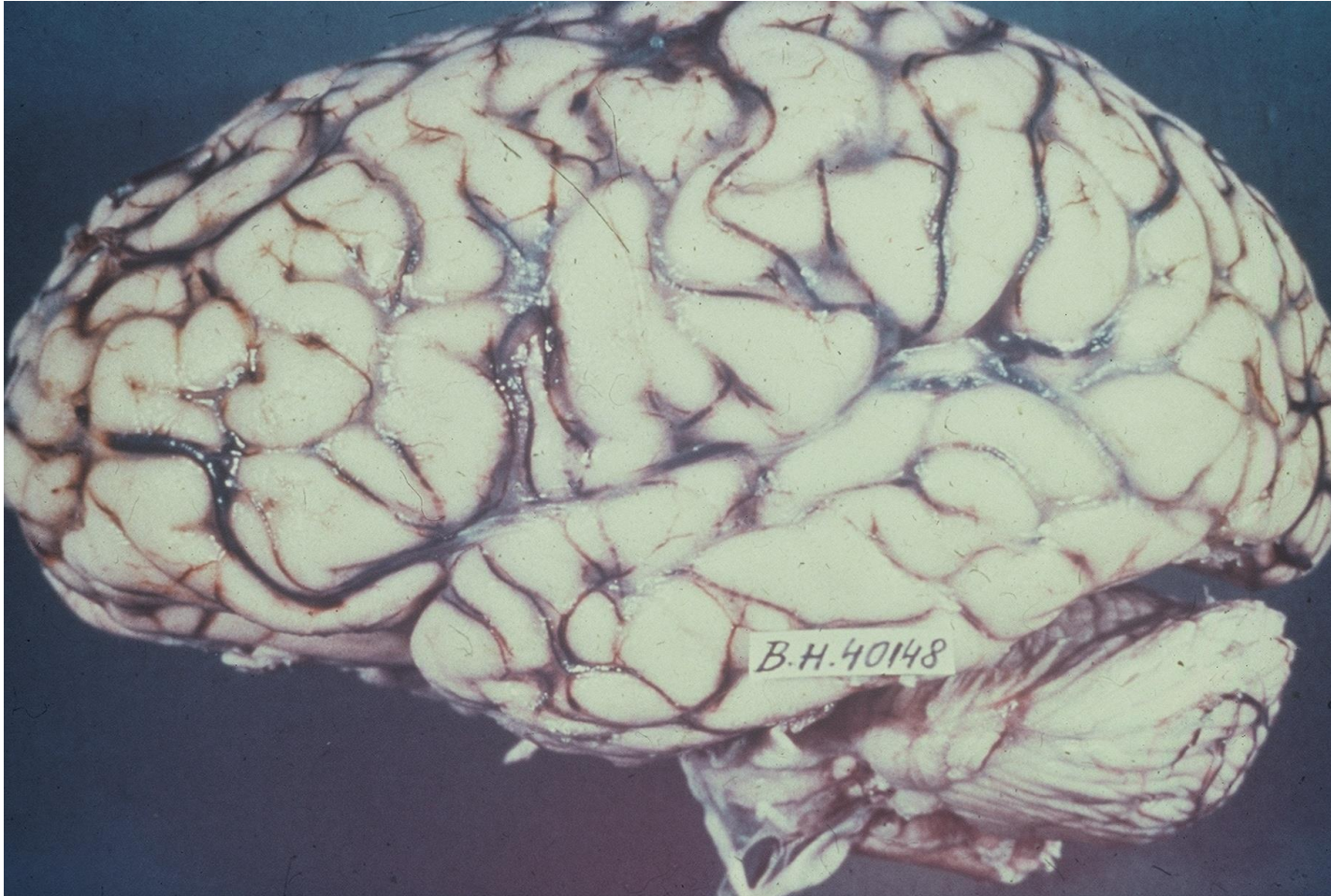
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## #2. What do we know about the Brain?

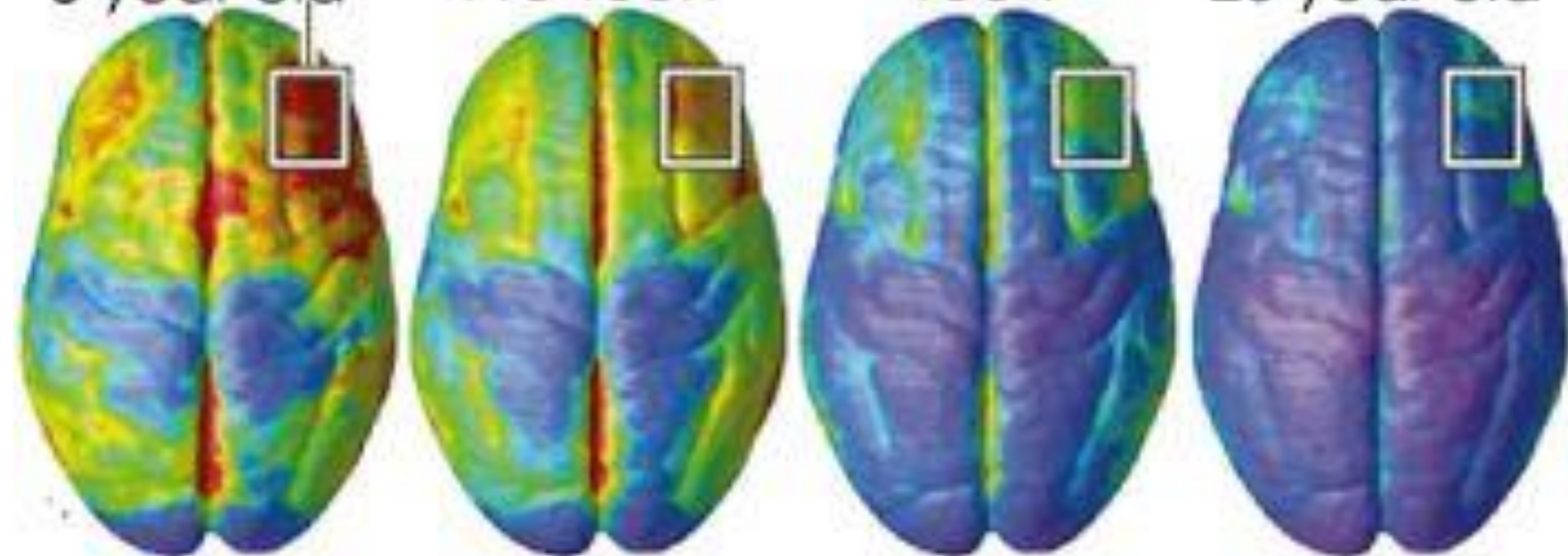


5 year old

Pre-teen

Teen

20 year old



Red/yellow:  
Less mature

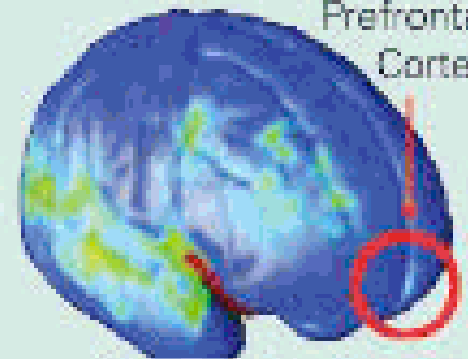
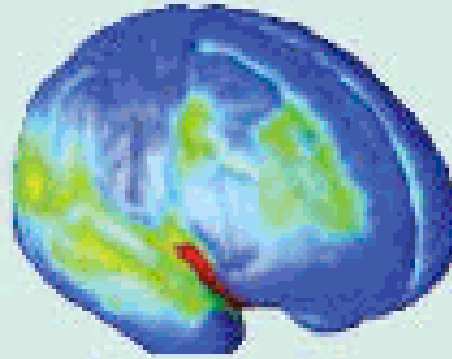
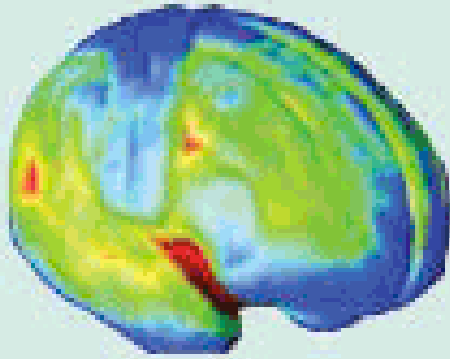
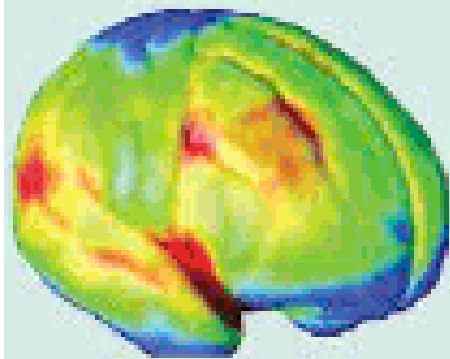


Blue/purple:  
More mature

AGES

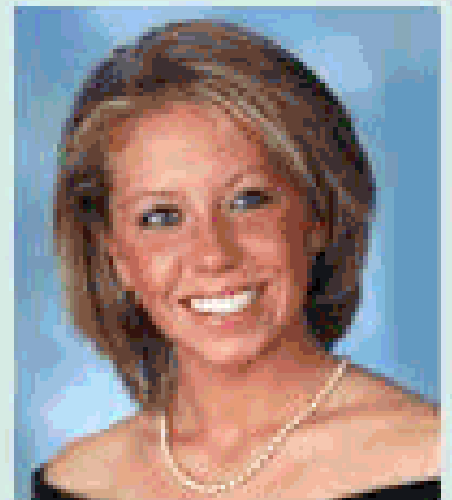
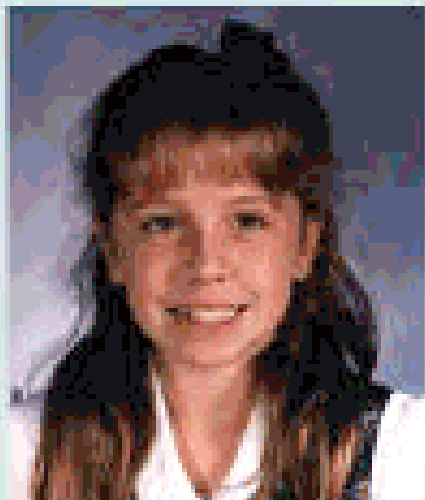
5

20



Prefrontal Cortex

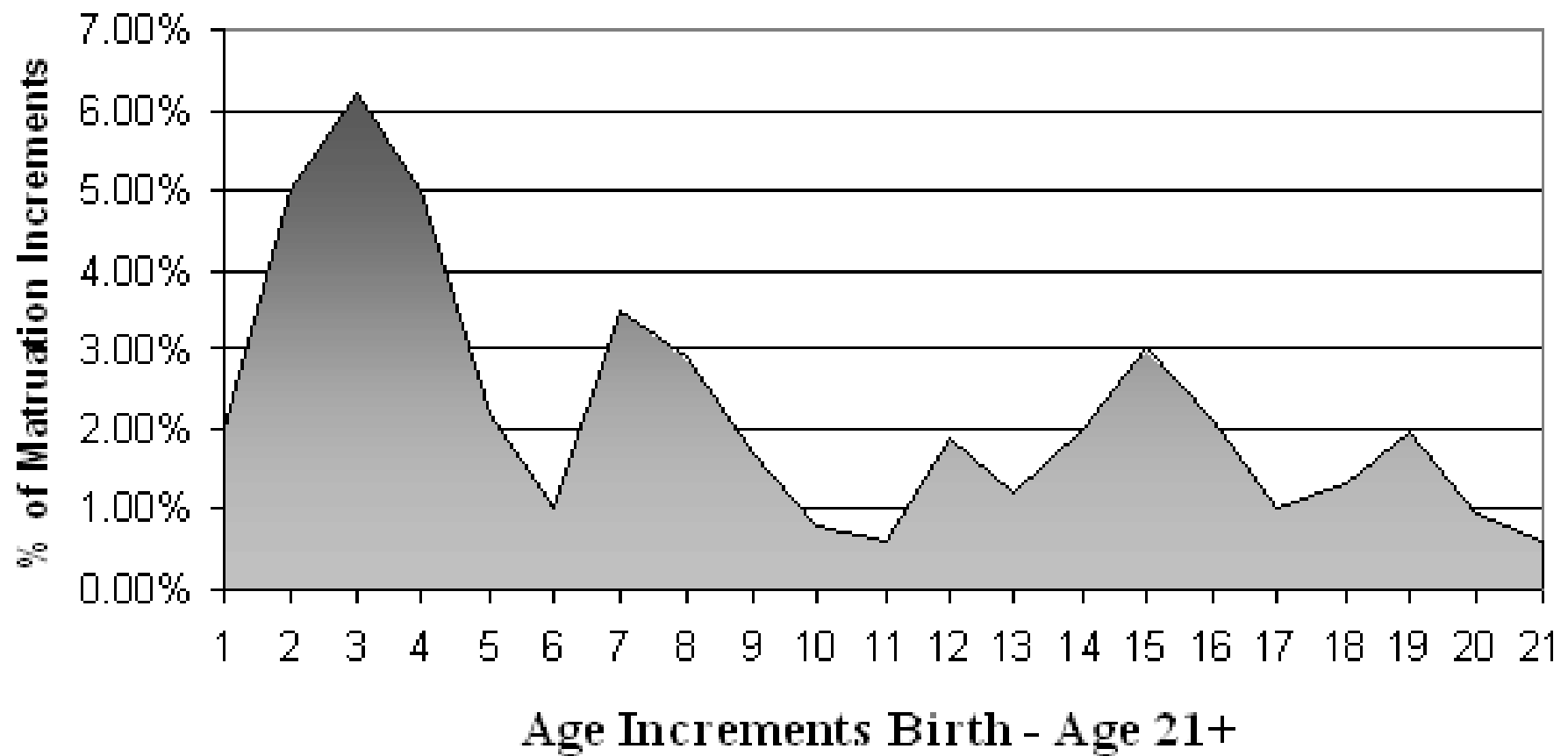
Blue represents maturing of brain areas.





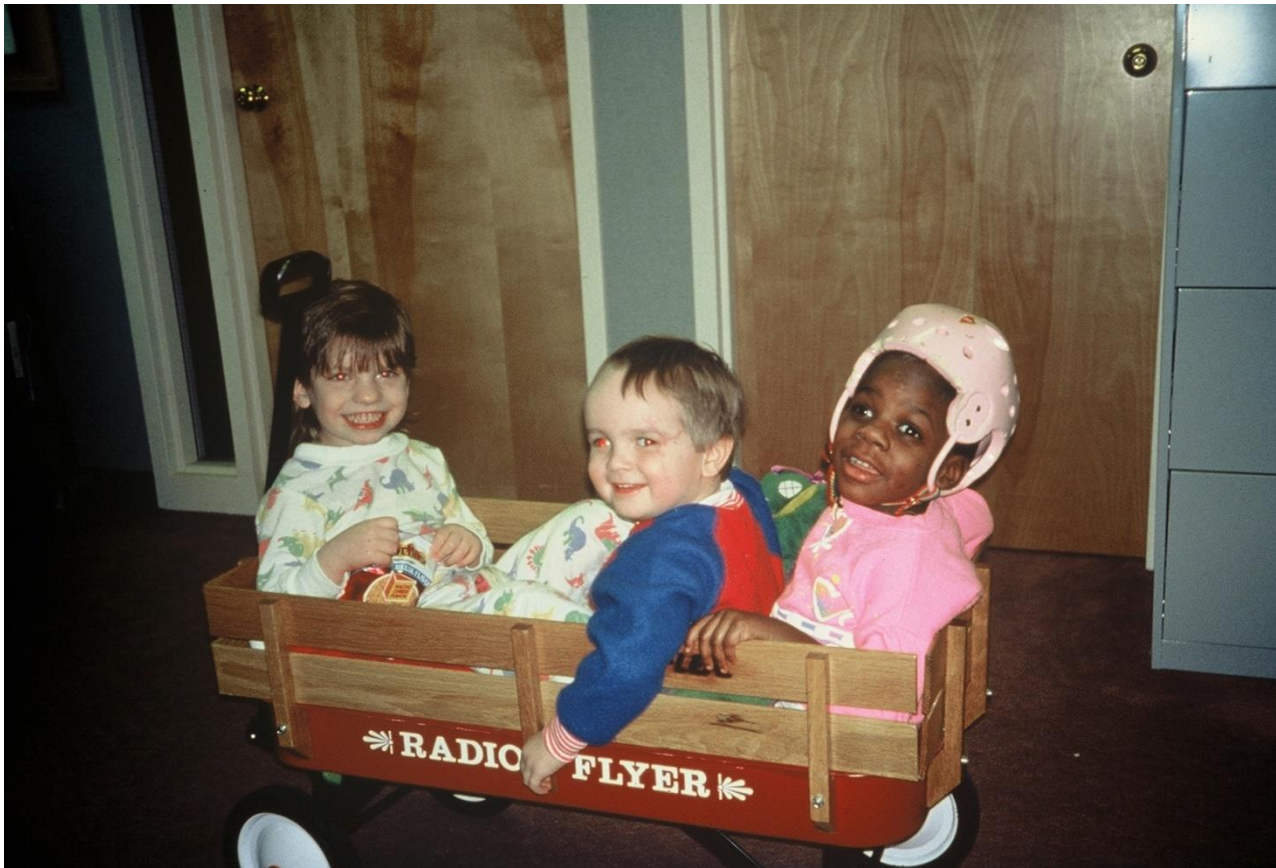


## Overall Brain Maturation





# **#3. What do we know about TBI in this population?**



# Educational, Vocational, Psychosocial, and Quality-of-Life Outcomes for Adult Survivors of Childhood Traumatic Brain Injury

Vicki Anderson, PhD; Sandra Brown, BA; Heidi Newitt, DPsych; Hannah Hoile, BA

**Objective:** To examine long-term outcomes from child traumatic brain injury (TBI) and relevance of injury severity. **Design:** A retrospective cross-sectional design. **Participants:** One hundred and twenty-four young adult survivors of childhood TBI (81 men), aged 18 to 30 years at evaluation (mean = 23.5, SD = 2.9), with injury on average 13.7 years prior to evaluation divided according to injury severity: mild ( $n = 60$ ), moderate ( $n = 27$ ), and severe ( $n = 37$ ). **Main Measures:** Questionnaires assessed educational and employment status, psychosocial function, and quality-of-life issues. **Results:** Functional difficulties persisted into adulthood. Injury severity was a particularly strong predictor of long-term outcomes, with environmental factors playing a less consistent role. Survivors of severe TBI were particularly vulnerable, demonstrating global impairment: poorer school performance, employment difficulties, poor quality of life, and increased risk of mental health problems. Mild and moderate TBI were more benign, although lower educational attainment and employment status were identified, and moderate TBI was associated with late developing mental health issues. **Conclusions:** Traumatic brain injury is a lifelong problem, compromising the individual's capacity to meet developmental expectations across a wide range of functional domains. **Keywords:** *child, education, long-term outcomes, quality of life, traumatic brain injury, vocation*

**T**RAUMATIC BRAIN INJURY (TBI) is a major cause of mortality and disability, with recent census data reporting that two-thirds of survivors of serious acquired brain insult experience impairments that restrict participation in normal daily activities.<sup>1</sup> For children, such injuries represent a common interruption to normal development, occurring at an annual rate of 250 per 100 000.<sup>2</sup> Consequences of adult TBI are well established, with findings indicating significant problems (physical, cognitive dysfunction, educational, vocational opportunity, psychological), persisting even several decades postinjury.<sup>3,4</sup> In comparison, the long-term consequences of childhood TBI remain poorly understood.

One of the major difficulties faced by professionals working with children with TBI is predicting outcomes and determining priorities for intervention and follow-up.<sup>5</sup> Some researchers argue for the importance of

ous and persisting sequelae, even after the mildest of insults.<sup>6,7</sup> Such claims are provocative and behoove researchers to carefully consider their outcome data to provide healthcare professionals and families with accurate predictions. Such information is of particular significance for children, for whom there is the opportunity to maximize both recovery processes and ongoing developmental progress. However, opportunities to follow children into adulthood are limited. It is likely that clinical perceptions of long-term outcomes may be negatively skewed, with clinical referrals often biased to those children with severe ongoing problems seeking access to advice and resources in the long-term postinjury.

The handful of studies to date that have followed survivors of childhood TBI into adulthood have produced somewhat conflicting results, possibly due to the inherent methodological problems of longitudinal research,



## Cognitive outcome in children and young adults who sustained severe and moderate traumatic brain injury 10 years earlier

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(Received 6 July 2009; revised 23 August 2009; accepted 24 August 2009)

### Abstract

**Objective:** This study is a population-based, retrospective follow-up study of neuropsychological functions after severe and moderate TBI.

**Methods:** One hundred and sixty-five survivors of TBI injured in 1987–1991 in the 0–17-year age group were identified. Of the traceable individuals (149), 53 patients who sustained injury at a mean of 9.96 years participated in a neuropsychological investigation 10 years post-injury. A control group of 40 healthy subjects, matched for age and sex was chosen. An extensive neuropsychological test battery was used.

**Results:** The TBI group showed significantly poorer performance in tests of intellectual function, with substantially lower results in verbal tests and in tests of verbal learning and memory, visuo-constructive ability and executive functions. The severely injured group showed substantial recovery. Poor results in visuo-constructive tests and tests of executive functions remained.

**Conclusions:** Severity of injury is an important factor when assessing outcome, even 10 years after childhood TBI. The TBI group obtained poorer results on most of the measurements compared with healthy controls. Verbal function was strongly affected which needs to be taken into consideration when preparing for rehabilitation programmes. Evaluations of final outcome should not be made before the subjects reach adulthood.

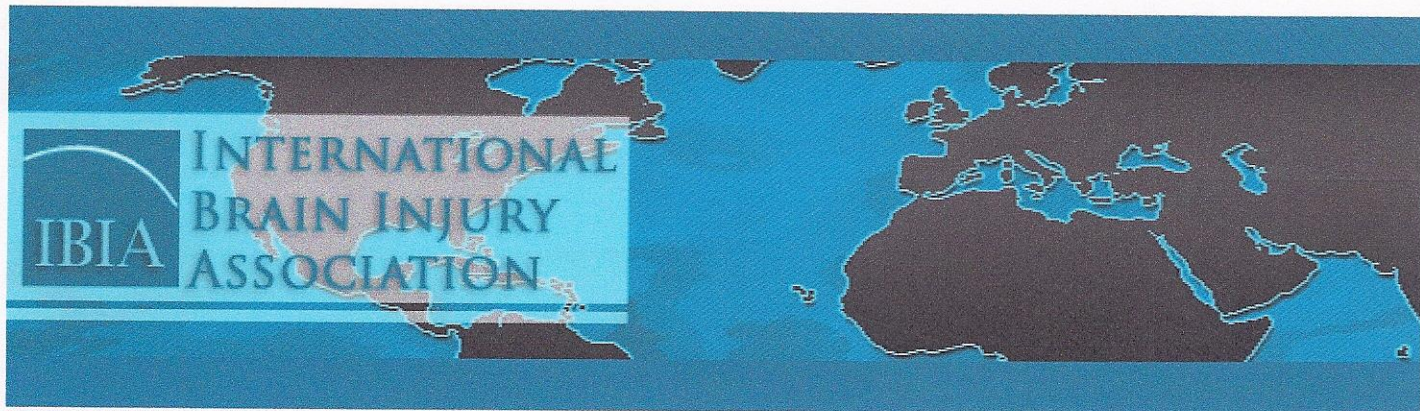
**Keywords:** Children, traumatic brain injury, cognitive long-term outcome

### Introduction

Children with severe traumatic brain injury (TBI) have displayed substantial neuropsychological impairment immediately after injury, some improvement during the first year and significant residual impairment 2 years post-injury [1, 2]. Research from

(WISC-III and WAIS-R) reveal that non-verbal skills are particularly likely to be affected [7]. The results of longitudinal studies reveal, however, that children appear to demonstrate significant recovery in intellectual function. The largest increases appear





## The Developing Brain after TBI: Predicting Long Term Deficits and Services for Children, Adolescents and Young Adults

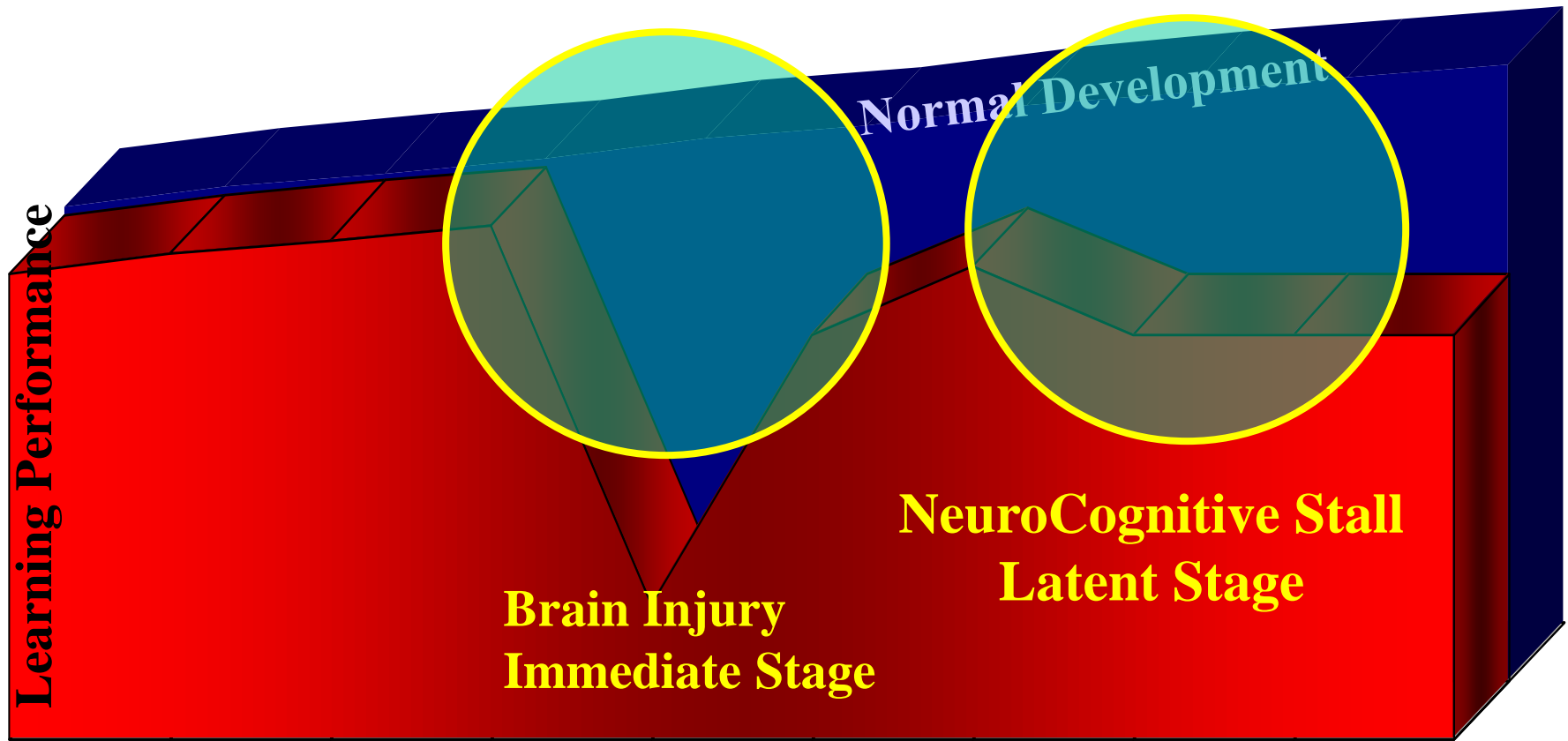
By:

Ronald C. Savage, Ed.D., President, North American Brain Injury Society

Traumatic Brain Injury (TBI) is a leading cause of death and disability in children, adolescents and young adults around the world (WHO, 2009). It is also internationally recognized that TBI can have a negative impact on continued brain maturation and development in young people as they get older and grow into their adult years (Lehr and Savage, 1991; Klonoff et al, 1993; Anderson et al, 1997, 1999, 2000, 2004, 2005, 2009; Hanaoka et al, 1998; Savage, 1999; Benz et al, 1999; Ewing-Cobbs et al, 1998, 2003, 2006; Chapman et al, 2001, 2003, 2007; Jang et al, 2002; Poogi et al, 2003; Hawley, 2003; Jonsson et al, 2004; Bauer and Fritz, 2004; Yeates et al, 2005; Ducrocq et al, 2006; Horneman and Emanuelson, 2009). A particular challenge for physicians, clinicians and therapists is accurately predicting the long term effects of TBI on young people so that services and supports can be organized before deficits worsen and/or young people fail altogether. Understanding TBI in this population as a *developing disability* over time can help better manage this disease-like process. This article discusses current neuroscience research regarding brain development and the cumulative indicators related to TBI recovery in order to help professionals better predict the long term needs of children, adolescents and young adults with TBI.

# NeuroCognitive Development after BI in Children/Youths

(Chapman, 2008)



Age: BI X yrs.....X yrs...X yrs...X yrs...X yrs...X yrs...X yrs...



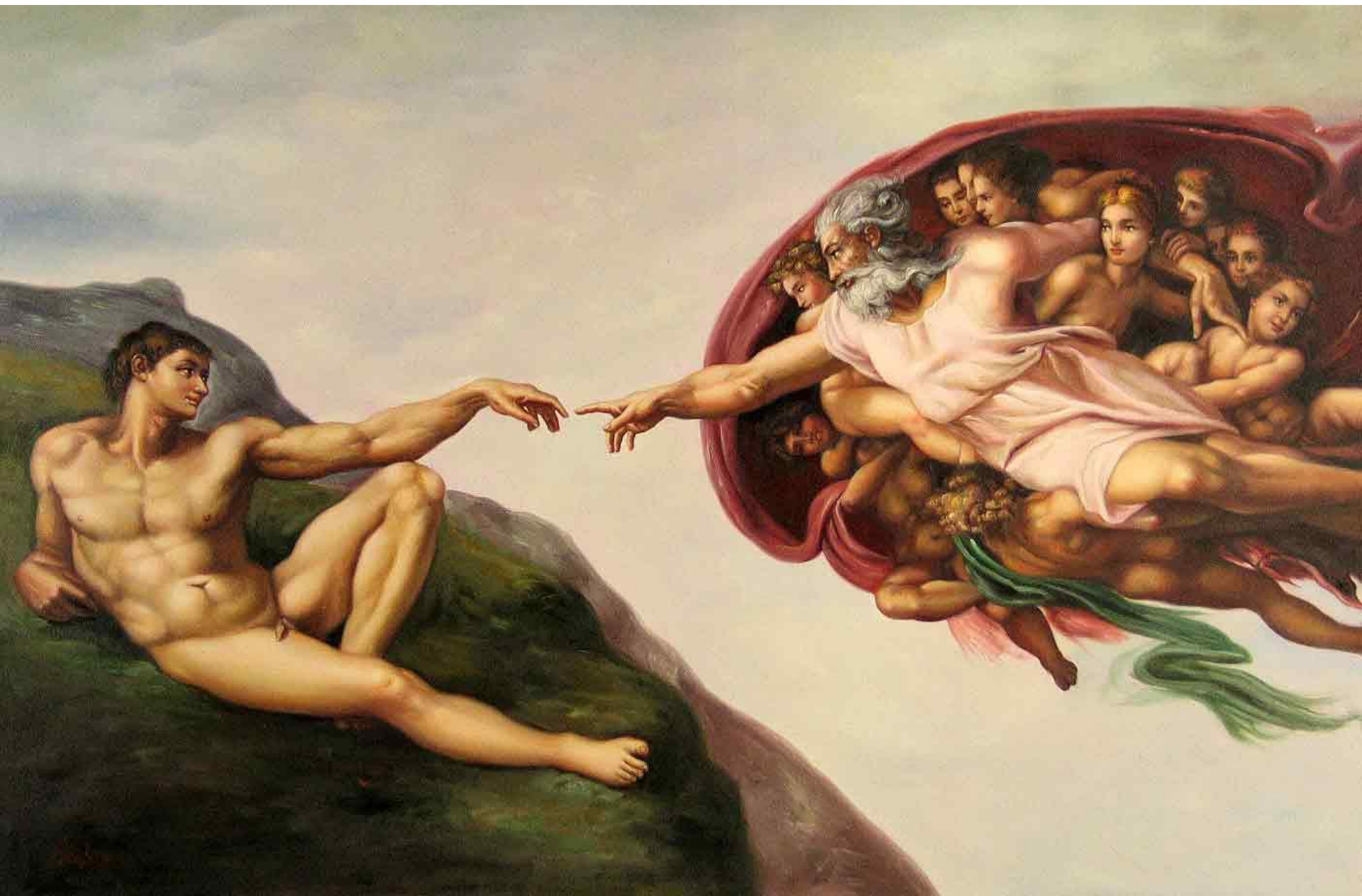










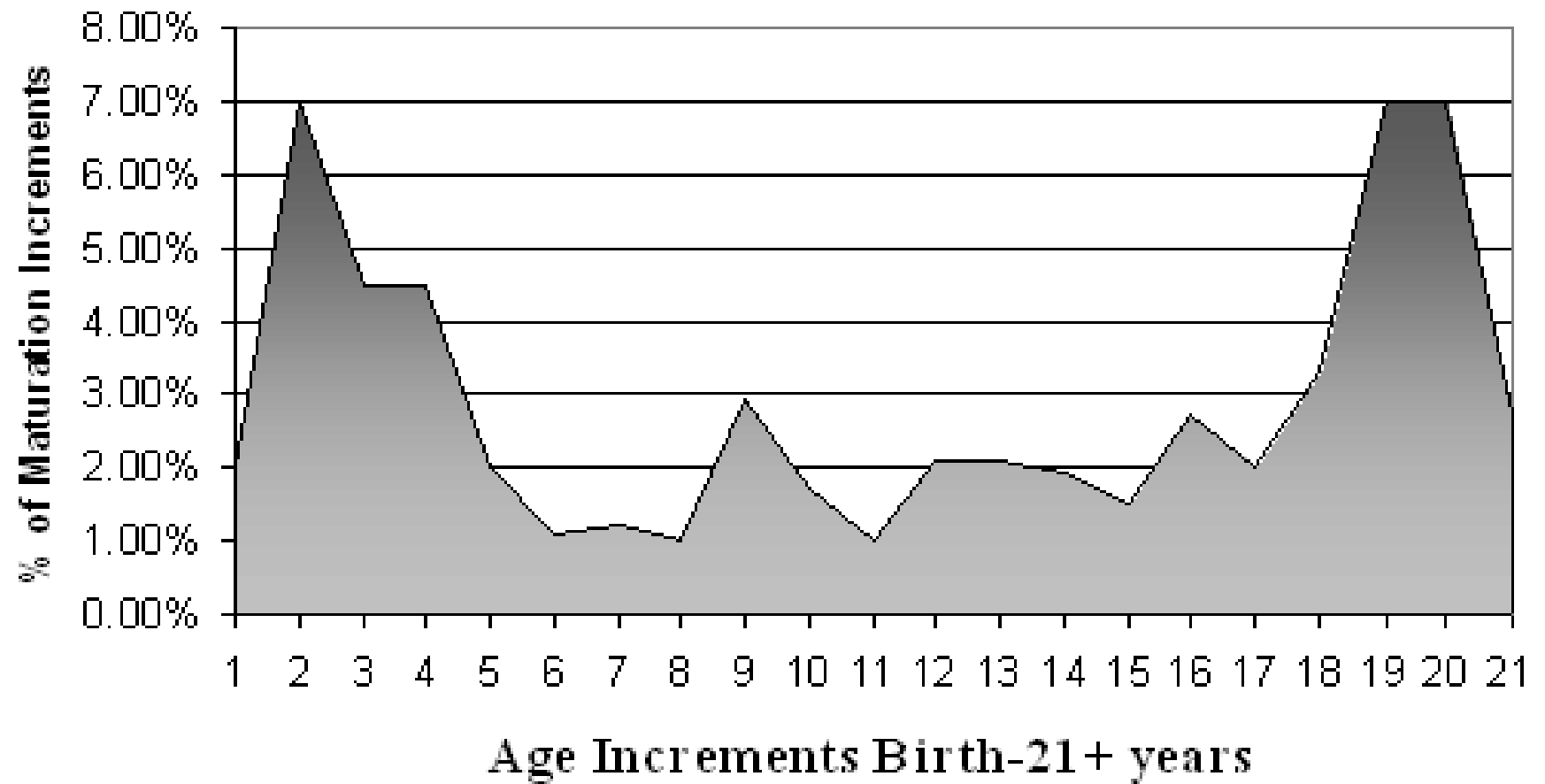








## Frontal-Temporal Region



# #4 How Do We Pull this All Together:

## Allostatic Load Theory

To understand how these other multiple and cumulative indicators can impact TBI recovery and functioning, it may be useful to incorporate allostatic load theory into our clinical practices. Savage (2004) reported on the use of allostatic load theory as a methodology to help predict the long term deficits and needs of young people with TBI. Allostatic load theory (NIH, 2003; Goldstein and McEwen, 2002, McEwen and Wingfield, 2003) refers to understanding how multiple factors can impact response to injury, including injury severity, post traumatic stress disorder (PTSD), individual differences, genetic makeup, psychosocial challenges, adverse environments, behavioral lifestyle, and other stressors (NIH, 2003). Allostasis, a conceptual expansion of homeostasis, is defined as “the continuous process that the host (individual) undergoes in the face of potentially stressful challenges (load).” (NIH, 2003). A modified allostatic load index has even been developed for humans to assess recovery trajectories from knee surgery and to identify factors that best predict success. Furthermore, Bay (2005) studied the allostatic load and depression after brain injury in adults and found a significant relationship between measures used to diagnose mild brain injury (MTBI) and those individuals at risk for developing depressive symptoms after MTBI.

## “Predicting” (Prognosis) for Deficits and Services

**A** = Severity and type of brain injury

**B** = Age at the time of injury

**C** = Pre-existing factors

**D** = Available resources

$$A+B+C+D = X$$

**X** = *Prediction of deficits and long term needs*

# BRAIN INJURY

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professional

## Brain Injury as a Chronic Condition

Rethinking Brain Injury

Implications for Public Policy

Implications for Education

Implications for Medical Practice

Implications for Research

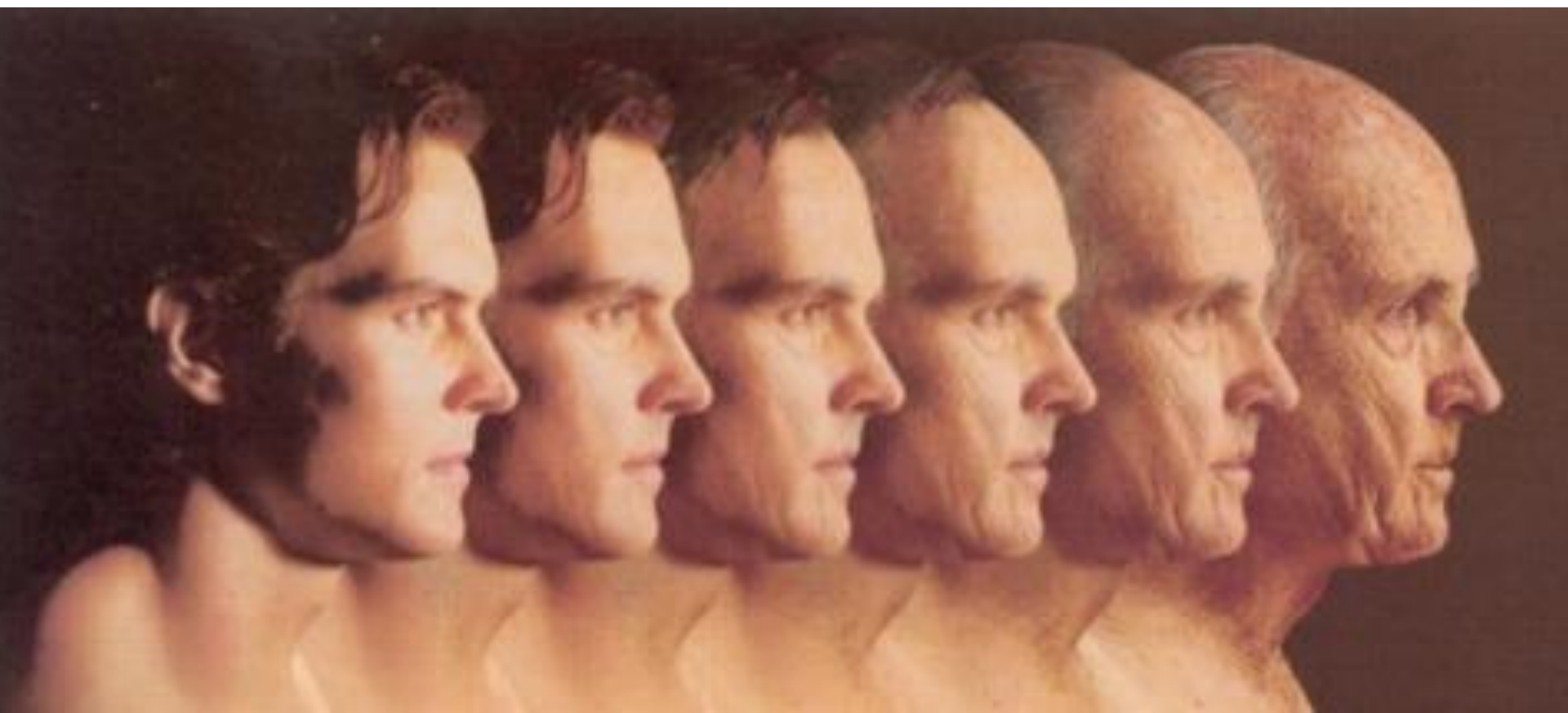
Implications for Psychosocial Interventions

# Brain Injury as a Chronic Disease Process

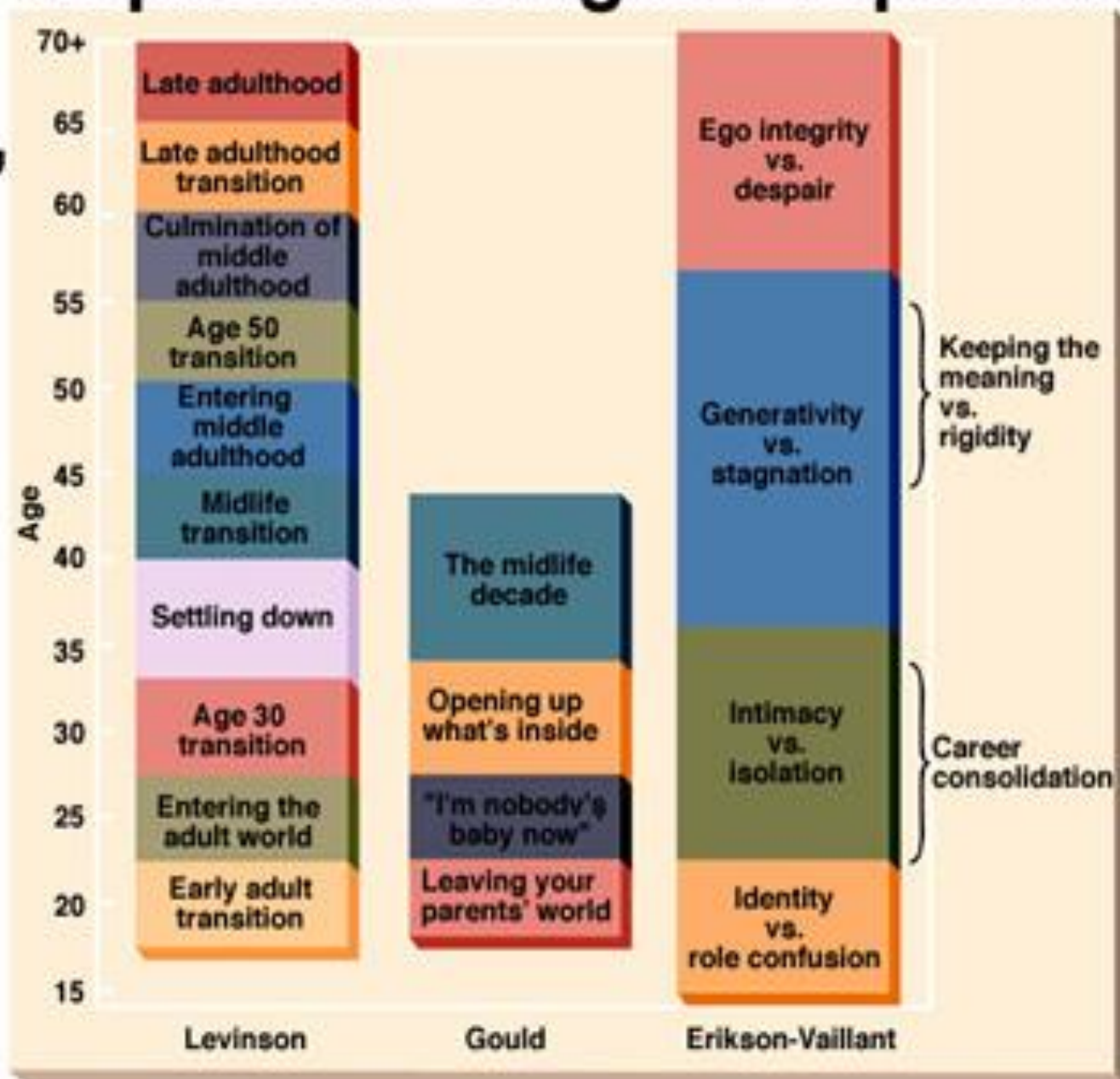
- Cognitive decline
- Psychiatric / NeuroBehavioral problems
- Early Dementia / Alzheimer's
- Parkinson
- ALS (Lou Gehrig's disease)
- Vision, hearing, sleep disorders
- Neuro-endocrine disorders (growth, thyroid)
- Sexual dysfunction
- Muscular / Skeletal dysfunction

» Masel, B. 2009, 2010





# Adult Developmental Stages Proposed by Levinson, Gould, and Vaillant

















# Summary . . .

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- Brain Injury is best seen as a “developing” and “chronic” problem over time
- We need to understand child / adult neuro-dev, human brain research, and BI to fully understand the impact on the person as s/he ages
- *Allostatic Load Theory* enables us to factor multiple variables to better predict deficits and services
- See BI as a *chronic disease process* –

***Time to Focus Upon a CURE***

