Imaging the Relevance of Sleep for Brain Function
Chair: Julie Carrier, Université de Montréal; Center of Advanced Research in Sleep Medicine, Hopital du Sacre-coeur de Montreal, Montreal, QC, Canada

Recent sleep studies using a multi-modal brain imaging approach (structural and functional MRI, PET, MRS, TMS and high-density EEG) made significant advancement in understanding the role of sleep in brain functions and cerebral plasticity. These studies demonstrate important reciprocal interactions between sleep and wakefulness on regional brain function. In this symposium, we will present emerging data on neural correlates of cognition during a normal waking day and during sleep loss. We will show that dynamic changes in brain responses evolve across the sleep-wake and circadian cycles in a regionally-specific manner. We will also demonstrate that even a single night of total sleep deprivation affects decision making and its neural correlates. Importantly, we will discuss neural correlates of non rapid eye movement (NREM) sleep oscillations and how regional brain activity during sleep is modified by previous waking experience. The role of sleep and of specific sleep stages on neural correlates of motor learning consolidation will also be presented. Finally, we will illustrate the value of using the arsenal of brain imaging tools that have been developed in human cognitive neuroscience to tackle the underlying mechanisms of insomnia. Intriguingly, some of the results suggest that part of the structural deviations that have been reported in psychiatric diseases might in fact relate also to the disturbed sleep that most of these patients have, not necessary only to the psychiatric illness in itself. This symposium will provide insights on the interaction between sleep and waking activity, and their influence on regional brain activity in humans.

Learning Objectives: Having completed this symposium, participants will be able to:
1. Understand how neural correlates of learning and cognition during wakefulness are modulated by specific sleep states, acute sleep loss and insomnia;
2. Discuss how brain activity during sleep is modulated by previous wake activity; and
3. Illustrate how insomnia might account for some of the structural deviations in psychiatric disease.

Reciprocal Interactions Between Sleep and Wakefulness
Pierre Maquet, Cyclotron Research Centre, University of Liège, Liege, Belgium

Why wakefulness has to alternate with sleep is still incompletely understood. We used functional neuroimaging (PET, fMRI, EEG/fMRI) both during wakefulness and sleep in normal human volunteers to demonstrate the reciprocal interactions between these vigilance states on regional brain function. In a first set of studies, we characterized the neural correlates of cognition during a normal waking day and during sleep-loss. The data show that dynamic changes in brain responses evolve across the sleep-wake and circadian cycles in a regionally-specific manner in such a way that the allocation of cortical resources through subcortical activation is constrained by sleep pressure and circadian phase. In a second set of studies, we characterized the neural correlates of the main non rapid eye movement (NREM) sleep oscillations, spindles and slow waves, demonstrating regionally-specific transient surges of activity time-locked to these sleep events. A last set of studies aimed at showing that the regional brain activity is modified by previous experience, for instance during NREM sleep following spatial learning. These studies provide some insights on the interaction between sleep and waking activity, and their influence on regional brain activity in humans.

Sleep and Motor Memory Consolidation
Julien Doyon, Université de Montréal; Functional Brain imaging Unit, Montreal, QC, Canada

Memory consolidation refers to processes of brain plasticity by which experiences result in enduring long-term changes in neural representations. Recent behavioral studies in both animals and humans as well as brain imaging studies in volunteer subjects have demonstrated that sleep can influence the consolidation of motor skilled behaviors, especially abilities that are sequential in nature. In this presentation, I will present the results of a series of studies demonstrating that sleep during the night or day (nap) is essential for triggering the consolidation of a newly learned sequence of movements. I will then report the results of the polysomnographic recordings suggesting that the consolidation of such motor skilled behaviour is associated with Non-REM sleep, and with
changes in spindles during Stage 2 sleep, in particular. Finally, I will discuss our findings from functional magnetic resonance imaging (fMRI) studies and data-driven functional connectivity analyses revealing differences in the neural networks mediating the consolidation process of motor sequence learning, as well as the association observed between sleep parameters and changes in these neural substrates following motor memory consolidation.

Sleep Deprivation and its Effects on Risky Decision Making and Evaluation
Michael Chee, Duke-NUS Graduate Medical School, Singapore, Singapore

Behavioral and functional imaging studies have shown that even a single night of total sleep deprivation can result in alterations in cognitive performance and brain activation. In contrast, there have been relatively few investigations into how sleep deprivation affects decision making. Individuals performing a monetary gambling task showed higher nucleus accumbens signal when making higher risk choices. When encountering losses, the same individuals showed attenuated signal in the insula and orbitofrontal cortex corresponding to reduced response to loss. In a separate incentive compatible decision making task that involved mixed gambles spanning potential gains and losses, volunteers could choose to maximize gains or increase the overall probability of winning. When sleep deprived, a majority of volunteers evidenced an overall strategy shift towards maximizing gains. The change in economic preferences correlated with increased ventromedial prefrontal and decreased anterior insula activation. These in economic preferences did not correlate with changes in psychomotor vigilance. Finally, we found a shift in relative evaluation of social and monetary rewards in a mixed incentive delay task whereby the evaluation of social rewards as reflected by amygdala activation was altered with sleep deprivation. Given the pervasive nature of voluntary sleep curtailment, these findings encourage further investigation into decision making and its neural correlates in this setting.

Imaging Causes and Consequences of Insomnia
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Affecting about 10% of the population, insomnia is the most common health complaint in general practice. While insomnia has serious consequences, e.g. being the major risk factor for the development of psychiatric disorders, our understanding of its brain mechanisms is very limited. Investigations into the causes and consequences of insomnia have to a large extent applied theoretical frameworks and methods that are rooted in psychology. The present lecture provides examples that illustrate the value of application of the arsenal of brain imaging tools that have been developed in human cognitive neuroscience, to tackle the underlying mechanisms of insomnia. The overview includes recent and studies that apply structural and functional MRI, PET, MRS, TMS and high-density EEG. Intriguingly, some of the results suggest that part of the structural deviations that have been reported in psychiatric diseases might in fact relate also to the disturbed sleep that most of these patients have, not necessarily only to the psychiatric illness in itself. Concertedly, the brain imaging results in part support current models of insomnia but also provide new avenues to explore for a better understanding of mechanisms of vulnerability and possibilities for treatment.