Disclaimer: What's in this presentation can't be (yet) called proper science

- It is just an interim presentation on a scientific article that I'm slowly drafting
- You should take at least the following into account:
  - The presentation (as opposed to the article) doesn't associate particular references to particular claims
  - The presentation doesn't gauge the weight of the evidence for each factor (For example, the EGCG experiments have been done on mice, so they might not hold for humans, with our different biochemistry and proportions)
  - The presentation doesn't discuss what's still missing from the complete picture. For example, we don't know the relative bioavailabilities of the different compounds, or the relative sizes of their effects in their interaction.
Introduction

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- Yet, studies show that the different types of processing do not alter the caffeine content of the leaves (at least not more than 0.3%)
Introduction

- It is a common perception that black tea contains more caffeine than green. Another common claim is that white tea has the least amount of caffeine.
- Yet, studies show that the different types of processing do not alter the caffeine content of the leaves (at least not more than 0.3%)
- So, are these perceptions and claims mere myths, or what is happening here?
Factors Affecting the Amount of Caffeine in Tea

• Perceived:
  – Interactions with other psychoactive compounds in tea

• Actual:
  – Plant variety
  – Growing conditions
  – Selection in plucking
  – Processing methods
  – Brewing parameters
  – Store selection
Factors Affecting the Amount of Caffeine in Tea

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Other Psychoactive Compounds in Tea

• The polyphenol epigallocatechin-gallate (EGCG)
• The amino acid L-theanine
Epigallocatechin-Gallate (EGCG)

- Acts exactly like benzodiazepine-based tranquilizers
Epigallocatechin-Gallate (EGCG)

- Acts exactly like benzodiazepine-based tranquilizers

Elevated plus-maze test

Step-down type passive avoidance test
The Amino Acid L-Theanine

- L-theanine alone reduces stress responses
- Yet, alone it also
  - Lowers task-solving capability and alertness
  - Increases feelings of mental and physical fatigue
  - Causes head-aches
With Caffeine, L-Theanine Interacts In a Complex Manner

- Caffeine alone
  - Increases alertness
  - Aids in tasks requiring focusing ability and vigilance
- L-theanine taken with caffeine
  - Boosts the effects of caffeine
  - Uniquely gives a sense of being calm, alert and focused
  - Leads to a more relaxed feeling
Factors Affecting the Perceived Amount of Caffeine in Tea

→ EGCG in tea diminishes the perceived amount of caffeine

→ L-theanine diminishes some experienced effects of caffeine, such as “jumpiness”
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Effect of Plant Variety

- The two main subspecies of tea are *Camellia Sinensis* var. *Sinensis* and *Camellia Sinensis* var. *Assamica*
- Use of purposely cultivated clonal tea varieties is growing
- Assamica-derived cultivars contain more catechins than Sinensis-derived
- Results for caffeine are contradictory
Effect of Plant Variety

- Between individual cultivars differences can be huge
  - Regularly up to 250%
  → Cultivar plays a big part in level of caffeine, but there is no simple mapping between cultivars and tea types.
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Effect of Growing Conditions

- The polyphenol and caffeine profiles of leaves can be used to train a classifier accurately discerning the geographic origin of the teas.
Effect of Growing Conditions

- Studies on weather effects contradictory (maybe because weather effects hard to isolate)
- High temperatures, long sun exposure time and high rainfall may either increase or lower EGCG and caffeine levels. L-theanine seems to react opposite
- Japanese gyokuro contains high L-theanine and caffeine levels, but lower EGCG because it is shaded for two weeks before harvesting
Effect of Growing Conditions

- Teas grown at higher altitudes contain more EGCG than those grown at lower altitudes.
- Teas grown at lower altitudes had less EGCG in the spring than in autumn. But when grown high, there was no such difference.
- First spring harvest may have as much as 5 times the L-theanine content of later harvests, even when EGCG and caffeine levels stay constant.
Effect of Growing Conditions

→ Geography, weather and seasonal changes affect the amounts of caffeine, EGCG and l-theanine in tea, but there isn't a clear consensus or a mapping to tea types we could use.

→ Provisionally, l-theanine content is higher in spring teas used commonly for high-quality green teas.

→ The amount of EGCG is higher in quality teas grown at higher altitudes.
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Effect of Selection in Plucking

- Tea plants concentrate both EGCG and caffeine into the growing buds and shoots.
- Percentage of buds and smaller leaves correlates with higher quality teas, thereby increasing the caffeine and EGCG content.
- White teas are commonly made from buds and top leaves. On average, their caffeine content is higher than for other teas.

→ High quality teas have distinctly higher average caffeine levels than other teas.
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Production Processes of Tea

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**Preliminaries**
- Shadowing of bushes prior to harvest (gyokuro, matcha, kabusecha)

**Harvesting**
- Fresh leaves and buds
  - In Japan
  - Kukicha/karigane = stems
  - Mecha = buds
  - Konacha = hake

**Long sun-air-withering (prevents complete oxidation)**
- First drying (withering, approx. 40-50% moisture left)
- Brusing the leaves to start oxidation
- Full oxidation in hot/humid environment
- Natural
- Shaping if needed
- Oven drying
- Black tea

**Very long sun-air-withering (prevents oxidation)**
- Natural weak oxidation
- Steaming (Japanese) asamushi = short fukamushi = long
- Pan-frying (Chinese)
- Light shaping/rolling while heated
- Oven/drying
- White tea

**By hand (Chinese, orthodox)**
- By machine (Japanese, CTC)

**Light bruising/breaking**
- Partial oxidation in humid wrapped in paper/clay
- Partial heating by pan-frying
- Shaping while heated
- Oven-drying
- Green tea

**Sun/air-withering**
- Light bruising/breaking
- Partial oxidation in hot/humid environment
- Partial heating by pan-frying
- Shaping/rolling while heated
- Oven-drying
- Yellow tea

**Shaping**
- Shaping (drying)
- Final drying (approx 3% moisture left)

**Post-processing**
- Grinding
- Matcha
- Roasting
- Houjicha
- Natural fermentation in storage
- Sheng pu-erh/heicha
- Artificial fermentation in hot/humid environment
- Shu pu-erh/heicha
- Scording in a pile of jasmine flowers
- Traditional jasmine tea
- Storage in clay jars, occasional re-roasting
- Aged oolong
- Smoking
- Lapsang

Effect of Processing Methods

- Different tea types made from the same plant have similar amounts of caffeine
  - Long wither increases caffeine content by 10%
  - Long oxidation lessens caffeine content by 15%

- In contrast, oxidation radically reduces EGCG levels to 1/10 of the original
Effect of Processing Methods

• Particle size of the processed tea affects the solubility of the relevant compounds
Effect of Processing Methods

- Particle size of the processed tea affects the solubility of the relevant compounds
  - With small particle size, most caffeine and EGCG is transferred into the drink almost instantly. With a larger particle size, the transfer rate is logarithmic.
Effects of Processing Methods

→ Oxidation of tea from green to black dramatically reduces the amount of EGCG, thus upsetting the balance in favour of caffeine

→ The CTC method, which is commonly used for low-quality black tea leads to much quicker solubility of caffeine and EGCG

→ Same goes for ground matcha green tea
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Effect of Brewing Parameters: Time and Temperature

- On a long time-scale, caffeine and EGCG extraction is linear with regard to temperature, logarithmic with regard to time
Effect of Brewing Parameters: Time and Temperature

- On actual tea brewing times, the relevant differences are that caffeine infuses quicker, while EGCG is more affected by temperature.
Effect of Brewing Parameters: Time and Temperature

→ Black teas are typically brewed for longer and in higher temperatures than other types of tea. Particularly the time dramatically increases the caffeine content of the drink.

→ The instructions for white teas differ both in temperature and in length, from 65°C to boiling and 30 seconds to 15(!) minutes.
Effect of Brewing Parameters: Vessel, Ratio and Movement

- A small teabag can slow infusion as much as 29% compared to loose teas
  - Especially, if the teabag is left stationary, infusion is linear. If the teabag is stirred, it returns to logarithmic
  - Increasing the size of the teabag increases infusion rate linearly, until the volume of the bag is 10 times the volume of the leaves
- Increasing the amount of leaves generally increases also the caffeine content linearly
- Increasing the water to leaf ratio increases rate of infusion
Fig. 2. Schematic exploded view of the inner compartment of the modified rotating diffusion cell. B, baffle; P, Parafilm; T, teabag paper. Hatched sections were made of stainless steel.
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Effect of Store Selection

- Black teas available in Middle-Europe
  - Have more caffeine and EGCG than green teas
  - Their instructions on average specify usage of more leaves, longer infusion times and more water
  - The leaves of black teas are more often CTC manufactured.
  - The green teas are more often artificially flavored (=generally of poorer original quality)
- In teas commercially sold in Australia, both the level of caffeine and L-theanine were higher in loose leaf teas than in tea bag teas
Conclusions

- Probable causes for the perception that black teas have more caffeine than others:
  - Black teas are often infused for longer times (and in higher temperatures)
  - Black teas are more often CTC teas
  - A combination of factors leads commercially available black teas to have more caffeine than their green or white counterparts
  - The amount of EGCG counteracting the effects of caffeine is much lower in black tea
Conclusions

- On the other hand, it may still just be a myth. Look at the claim that white tea has the least caffeine:
  - White teas in store selections actually contain on average more caffeine than other teas. This is probably because they are generally made up of buds and top leaves, which have a high caffeine content
  - If the white tea instructions specify a long infusion time and/or a high temperature, this caffeine is also readily transferred to the drink
Conclusions

- General guidelines: better quality teas generally contain more caffeine (and EGCG, l-theanine) than lower quality teas
  - Loose-leaf vs CTC/matcha powder
  - Loose-leaf vs bag
  - More buds and small leaves vs larger, older leaves
  - Higher-grown vs lower-grown