The material in the B lectures is extra and probably will not be covered.

1. Introduction and probability

- course goals, content, structure, requirements
- probability as a means of expressing uncertainty
- basic rules of probability; Bayes' theorem; Bayesian reasoning and inference
- permutations and combinations. `R functions: choose, gamma, factorial, combinations, permutations,`
- introduction to R: concept, data structures (`vector, matrix, data.frame`), syntax. Basic R functions for manipulation such as `c, cbind, rbind, [], sum, length, max, which.max, range`, ..., and for mathematics such as `log, log10, exp, sin, atan`, ...
- basic R statistical functions such as `mean, median, var, sd, mad, quartile, IQR`, ...
- data inspection and R plots: scatter plots, histograms. `R functions: plot, points, lines, abline, boxplot, hist, truehist{MASS}, mfrow, mfcol, par`, ...

2. Statistical models and probability distributions

- introdution to statistical models (modelling data)
- Bayesian hypothesis testing (model comparison)
- continuous probability distributions: distribution and density functions; expectation values
- working with the Gaussian distribution in R. `R functions: dnorm, pnorm, qnorm; qqnorm, qqline, qqplot, cumsum`
- summarizing probability distributions: expectation values, mean, variance, moments, skew, kurtosis. `R functions: polygon`
- random numbers and random number generators. `R functions: set.seed, sample, runif, rnorm`
- multiple variables: covariance. `R functions: cor, cov`
- multivariate (joint) probability distributions: conditional and marginal distributions. `R functions: mvrnorm`

3. Estimation, errors and uncertainty

- estimation
- the central limit theorem
- repeated measurements and $\sqrt{n}$ reduction in error; standard error in the mean
- measurement errors vs. uncertainties
- random and systematic errors

- principle of propagating errors: general derivation
- propagation of errors in one, two, many variables; fractional errors; weighted average
- confidence bounds and intervals intervals
- gamma distribution (in homework). `R functions: dgamma, pgamma, qgamma, rgamma`

4. Orthodox hypothesis testing

- degrees of freedom
- concept of orthodox hypothesis testing
- one sample tests
- Gaussian z statistic, t statistic, Student t-test and t distribution. `R functions: TDist: dt, pt, qt, rt; t.test`
- two sample tests
- p-values and the problem with orthodox hypothesis testing

4B. Supplement to Orthodox hypothesis testing

- Fisher F test: F statistic and F distribution. `R functions: df, pf, qf, rf; factor, var.test`
- relation between the χ^2 and F distributions
- summary of tests for Gaussian data
- non-parametric tests: KS test, Wilcoxon test. `R functions: ks.test, wilcox.test`
- pairwise tests (matched samples)

5. Linear models and regression

- least squares estimation of parameters of a 1D linear fit
- uncertainty estimates on the model parameters
- confidence intervals on predictions
- hypothesis testing with linear models
- linear model fitting with measurement errors
- measures of goodness of fit
- why least squares?
- linear regression in R: `R functions: lm, attributes, predict`
- single parameter nonlinear regression
- goodness of fit and the χ^2 distribution and test. `R functions: Chisquare: dchisq, pchisq, qchisq, rchisq`
- mulit-parameter linear regression

5B. Categorical regression

- types of variables: categorical data
- analysis of variance (ANOVA). `R functions: lm, aov, tapply, xyplot`
- ANOVA as linear regression
- multi-way ANOVA
- analysis of covariance (ANCOVA)
- comparing regression models using `anova`

6. Binomial and poisson distributions

- binomial distribution for binary processes. `R functions: dbinom, pbinom, qbinom, rbinom`
- logistic model and logistic regression
- Poisson distribution for counting processes. `R functions: dpois, ppois, qpois, rpois`
- Examples: radioactive decay; large telescopes
- the generalized linear model (GLM). `R functions: glm, jitter`
- modelling binominal and Poisson data using GLMs

7. Likelihood-based (Bayesian) parametric modelling

- data modelling with parametric models
- the prior, likelihood and posterior (probability density functions)
- conjugate priors; the beta distribution. `R functions: dbeta, pbeta, qbeta, rbeta`
- Is this coin fair? A Bayesian analysis (i.e. binomial likelihood, beta prior)

8. Bayesian modelling using Monte Carlo methods for sampling and integration

- why we need efficient sampling
- why uses of integration: marginalization, expectation, evidence, predicion
- Monte Carlo integration
- Monte Carlo sampling: rejection sampling, importance samping, MCMC: Metropolis–Hastings
- example of MCMC: fitting a straight line with unknown noise.
- new `R functions: density, %*%, drop, as.matrix, plotCI{glots}, rmvnorm{mvtnorm}, apply`
- included own `R functions: make.covariance.matrix, metrop` (uses function passing, and `noquote, formatC`) and example-specific `log.post`
- MCMC with `MCMCmetrop1R{MCMCpack}` in R (optional)

9. Maximum likelihood and density estimation

- maximum likelihood; least squares, χ^2
- density estimation
- histograms. `R functions: truehist{MASS}, hist`
- kernel density estimation: Gaussian and nearest neighbour kernels, nearest neighbours. `R functions: density`
- two-dimensional kernel density estimation. `R functions: kde2d, image, persp`

9B. Nonparametric and nonlinear regression

- the concept of regularization in regression and model fitting
- linear regression in matrix form (i.e. multidimensional linear regression)
- nonparametric regression: ridge regression; in the exercises `R functions: solve, ksmooth, locpoly{KernSmooth}`
- nonlinear regression. `R functions: nls`

10. Use and abuse of statistics

- Discovery of the Higgs boson? What p-values mean
- Simpsons paradox
- The stopping paradox, or the dependence of p-values on irrelevant information
- The three doors problem
- The three prisoners problem
- The danger – in orthodox hypothesis testing – of over-testing
- Do plane crashes come in clusters? Poisson processes