Maaslin 2 Analysis of GO Terms for COVIRT19

Lets install some R packages that we are gonna need to run this analysis

if(!requireNamespace("BiocManager", quietly = TRUE))

install.packages("BiocManager")

```
In [2]: | #if(!requireNamespace("BiocManager", quietly = TRUE))
              install.packages("BiocManager")
In [3]:
         #BiocManager::install("Maaslin2")
         #BiocManager::install('DESeg2')
         #BiocManager::install('phyloseg')
         #BiocManager::install('microbiome')
         #BiocManager::install("DirichletMultinomial")
         #install.packages("remotes")
In [4]:
         #remotes::install github("mikemc/speedyseg")
       Now lets load our libraries and set out environment
         library(tidyverse)
In [5]:
         library(phyloseq)
         library(microbiome)
         library(DESeq2)
         library(Maaslin2)
         library(parallel)
         library(DirichletMultinomial)
         library(pheatmap)
         library(ggpubr)
         library(viridis)
                                                                      - tidyverse 1.3.0 -
        — Attaching packages -

√ ggplot2 3.3.2

√ purrr 0.3.4

        ✓ tibble 3.0.4

√ dplyr 1.0.2

√ tidyr 1.1.2

√ stringr 1.4.0

                 1.4.0

√ forcats 0.5.0

        ✓ readr
```

```
— Conflicts -
                                                       tidyverse conflicts() —
X dplyr::filter() masks stats::filter()
X dplyr::lag()
                  masks stats::lag()
microbiome R package (microbiome.github.com)
 Copyright (C) 2011-2020 Leo Lahti,
    Sudarshan Shetty et al. <microbiome.github.io>
Attaching package: 'microbiome'
The following object is masked from 'package:ggplot2':
    alpha
The following object is masked from 'package:base':
    transform
Loading required package: S4Vectors
Loading required package: stats4
Loading required package: BiocGenerics
Loading required package: parallel
Attaching package: 'BiocGenerics'
The following objects are masked from 'package:parallel':
    clusterApply, clusterApplyLB, clusterCall, clusterEvalQ,
    clusterExport, clusterMap, parApply, parCapply, parLapply,
    parLapplyLB, parRapply, parSapply, parSapplyLB
The following objects are masked from 'package:dplyr':
```

combine, intersect, setdiff, union The following objects are masked from 'package:stats': IQR, mad, sd, var, xtabs The following objects are masked from 'package:base': anyDuplicated, append, as.data.frame, basename, cbind, colnames, dirname, do.call, duplicated, eval, evalq, Filter, Find, get, grep, grepl, intersect, is.unsorted, lapply, Map, mapply, match, mget, order, paste, pmax, pmax.int, pmin, pmin.int, Position, rank, rbind, Reduce, rownames, sapply, setdiff, sort, table, tapply, union, unique, unsplit, which.max, which.min Attaching package: 'S4Vectors' The following objects are masked from 'package:dplyr': first, rename The following object is masked from 'package:tidyr': expand The following object is masked from 'package:base': expand.grid Loading required package: IRanges Attaching package: 'IRanges' The following object is masked from 'package:microbiome':

The following object is masked from 'package:phyloseq':

coverage

distance

```
The following objects are masked from 'package:dplyr':
   collapse, desc, slice
The following object is masked from 'package:purrr':
    reduce
Loading required package: GenomicRanges
Loading required package: GenomeInfoDb
Loading required package: SummarizedExperiment
Loading required package: MatrixGenerics
Loading required package: matrixStats
Attaching package: 'matrixStats'
The following object is masked from 'package:dplyr':
    count
Attaching package: 'MatrixGenerics'
The following objects are masked from 'package:matrixStats':
    colAlls, colAnyNAs, colAnys, colAvgsPerRowSet, colCollapse,
    colCounts, colCummaxs, colCummins, colCumprods, colCumsums,
    colDiffs, colIQRDiffs, colIQRs, colLogSumExps, colMadDiffs,
    colMads, colMaxs, colMeans2, colMedians, colMins, colOrderStats,
    colProds, colQuantiles, colRanges, colRanks, colSdDiffs, colSds,
    colSums2, colTabulates, colVarDiffs, colVars, colWeightedMads,
    colWeightedMeans, colWeightedMedians, colWeightedSds,
```

colWeightedVars, rowAlls, rowAnyNAs, rowAnys, rowAvgsPerColSet, rowCollapse, rowCounts, rowCummaxs, rowCummins, rowCumprods, rowCumsums, rowDiffs, rowIQRDiffs, rowIQRs, rowLogSumExps,

```
rowMadDiffs, rowMads, rowMaxs, rowMeans2, rowMedians, rowMins,
            rowOrderStats, rowProds, rowQuantiles, rowRanges, rowRanks,
            rowSdDiffs, rowSds, rowSums2, rowTabulates, rowVarDiffs, rowVars,
            rowWeightedMads, rowWeightedMeans, rowWeightedMedians,
            rowWeightedSds, rowWeightedVars
        Loading required package: Biobase
        Welcome to Bioconductor
            Vignettes contain introductory material; view with
             'browseVignettes()'. To cite Bioconductor, see
             'citation("Biobase")', and for packages 'citation("pkgname")'.
        Attaching package: 'Biobase'
        The following object is masked from 'package:MatrixGenerics':
            rowMedians
        The following objects are masked from 'package:matrixStats':
            anyMissing, rowMedians
        The following object is masked from 'package:phyloseq':
            sampleNames
        Loading required package: viridisLite
         getwd()
In [6]:
         setwd('/home/jovyan/work/Jochum 3/jupyter lab/GO term analysis/')
        '/home/jovyan/work/Jochum_3/jupyter_lab/GO_term_analysis/R_Maaslin2'
         raw<-as tibble(read.table("Combined BALF GO Terms parent propagated.tsv", sep = "\t", row.names = NULL, header = T, quote
In [7]:
       A tibble: 47,233 x 2,020 # good so far now do a little regex and fix some stuff
         colnames(raw)<-gsub("NA tax", "unclass", colnames(raw))%>%str replace all("NC1 SRR7796663", "NC1.SRR7796663")
```

Transform the raw table by type of count (euk, term, bac, arc)

```
In [9]:
          df<-raw %>%
             select(GO term,namespace,depth,name,ends with(" counts"))%>%
             pivot longer(cols = -c(GO term, namespace, depth, name),
                          names_to = c("sample","type","abund"),#c("Total", "Archaea","Bacteria","Eukarya", "Viridae", "Unclassifie
                          names pattern = "(.*) (.*) (.*)")%>%
             select(-abund)%>%
            filter(value>1)%>%
             pivot wider(names from = sample, values from=value, values fill=0)
           #SIDE NOTE:There are multiple processes and values for a single sample so you cant convert the sample to columns
         Make individual tibbles for biological processes and molecular fxn
          bio<-filter(df, namespace=="biological process")</pre>
In [10]:
          mol<-filter(df, namespace=="molecular function")</pre>
         make individual tibbles for each type (bac, euk, term, arc, vir, etc)
          bio bac<-bio%>%filter(type=="bac")%>%select(-type)
In [11]:
           bio term<-bio%>%filter(type=="term")%>%select(-type)
           mol bac<-mol%>%filter(type=="bac")%>%select(-type)
          mol term<-mol%>%filter(type=="term")%>%select(-type)
         subselect tibbles for only the counts and go terminology
          bio bac counts<-bio bac%>%select(-c(namespace,depth,name))
In [12]:
           bio bac tax<-bio bac%>%select(GO term,namespace,depth,name)
          mol bac counts<-mol bac%>%select(-c(namespace,depth,name))
           mol bac tax<-mol bac%>%select(GO term, namespace, depth, name)
         convert them to dataframes for downstream import to phylsoeq
In [13]:
          bio bac counts<-data.frame(bio bac counts, row.names=1)</pre>
           bio bac tax<-data.frame(bio bac tax, row.names=1)</pre>
          mol bac counts<-data.frame(mol bac counts, row.names=1)</pre>
           mol bac tax<-data.frame(mol bac tax, row.names=1)</pre>
         convert the dataframes into phyloseq formats
          bio bac counts phy <- otu table(bio bac counts, taxa are rows=TRUE)
In [14]:
           bio bac tax phy <- tax table(as.matrix(bio bac tax), errorIfNULL=TRUE)
          mol bac counts phy<-otu table(mol bac counts, taxa are rows = T)</pre>
          mol bac tax phy<-tax table(as.matrix(mol bac tax), errorIfNULL = T)</pre>
```

import your metadata

```
bio bac sam<-as.data.frame(read.table("Combined BALF GO Terms metadata.txt",header = T, sep = "\t",row.names = 1))
In [15]:
        a little regex to fix the stupid filename
In [16]:
          rownames(bio_bac_sam)<-rownames(bio_bac_sam)%>%str_replace_all("NC1_SRR7796663", "NC1.SRR7796663")
          bio bac sam$accession<-rownames(bio bac sam)
         making physeg object
          bio bac pseq <- phyloseq(bio bac counts phy, bio bac tax phy, sample data(bio bac sam))
In [17]:
          mol bac pseq<-phyloseq(mol bac counts phy, mol bac tax phy, sample data(bio bac sam))
          bac pseq<-merge phyloseq(bio bac pseq,mol bac pseq)</pre>
          bac pseq
         phyloseq-class experiment-level object
         otu table()
                       OTU Table:
                                           [ 13846 taxa and 167 samples ]
         sample_data() Sample Data:
                                           [ 167 samples by 71 sample variables ]
         tax table()
                       Taxonomy Table:
                                           [ 13846 taxa by 3 taxonomic ranks ]
         filter out the negative control and unknown samples
In [18]:
          bac pseq no neg<-subset samples(bac pseq, sample type!="neg control")
          bac pseq no neg# [ 13846 taxa and 162 samples ]:
          bac pseq no neg<-subset samples(bac pseq no neg, sample type!="Unknown")
          bac pseq no neg# [ 13846 taxa and 141 samples ]:
         phyloseq-class experiment-level object
         otu table() OTU Table:
                                           [ 13846 taxa and 162 samples ]
         sample data() Sample Data:
                                           [ 162 samples by 71 sample variables ]
                                           [ 13846 taxa by 3 taxonomic ranks ]
         tax table() Taxonomy Table:
         phyloseq-class experiment-level object
         otu table()
                        OTU Table:
                                           [ 13846 taxa and 141 samples ]
         sample data() Sample Data:
                                           [ 141 samples by 71 sample variables ]
         tax table() Taxonomy Table:
                                           [ 13846 taxa by 3 taxonomic ranks ]
         Lets change the names of the Go Terms so we can understand the description as well as the tag
        This code was causing mismatches with name and GO TAG and has since been resolved 19 NOV 2020
          #names<-paste(taxa names(bac pseq no neq),qet taxa unique(bac pseq no neq,taxonomic.rank = "name" ),sep = "-")</pre>
In [19]:
          #taxa names(bac pseq no neq)<-names</pre>
         NEW and improved code
```

```
In [20]: tax<-data.frame(tax_table(bac_pseq_no_neg))
    names<-paste(rownames(tax),tax$name,sep="-")
    length(names)
    taxa_names(bac_pseq_no_neg)<-names</pre>
```

13846

DESeq2 VST transformation

```
In [21]: sample_info_tab<-sample_data(bac_pseq_no_neg)
    sample_info_tab_phy <- sample_info_tab)
    deseq_counts<-phyloseq_to_deseq2(physeq = bac_pseq_no_neg,design = ~ 1)
    deseq_counts_vst <- estimateSizeFactors(deseq_counts, type = "poscounts")
    vst_trans_count_tab <- assay(deseq_counts_vst)</pre>
```

converting counts to integer mode

YAAAAAAAAAAAAAASSSSSSSSSSS THANK YOU LIMMMA

IT FIXED THE BATCH EFFECT!

Dont worry about the limma batch effect correction step, I think I found a better way by including it in the multivariate model

```
In [22]: #vst_trans_count_tab2 <- limma::removeBatchEffect(vst_trans_count_tab, sample_info_tab$publication)</pre>
In [23]: vst_count_phy <- otu_table(vst_trans_count_tab, taxa_are_rows=T)
vst_tax_phy <- tax_table(bac_pseq_no_neg)
vst_physeq <- phyloseq(vst_count_phy, vst_tax_phy,sample_data(bac_pseq_no_neg))
vst_physeq_comp<-microbiome::transform(x = vst_physeq,transform = "compositional")</pre>
```

MaAsLIN2

```
In [24]: #dir.create("R_Maaslin2") # Create a new directory
setwd("/home/jovyan/work/Jochum_3/jupyter_lab/GO_term_analysis/R_Maaslin2/") # Change the current working directory
getwd() #check if directory has been successfully changed
```

'/home/jovyan/work/Jochum_3/jupyter_lab/GO_term_analysis/R_Maaslin2'

```
In [25]: df_input_data2<-data.frame(t(otu_table(vst_physeq_comp)))</pre>
```

```
df_input_metadata2<-data.frame(sample_data(vst_physeq_comp))</pre>
```

ok so here are the parameters you want to manipulate:

min abundance= the min rel abund hits (1%) #filters out XXXX GO_terms \ min prevalence = Min samples required with min abundance for a feature not to be filtered (0.1=10%=14.1000 samples) \ max_significance = the maximinum p adjusted value to be significant \

This will filter out 13770 GO TERMS \

normalization = *CLR transformation* \

CORRECTION dont normalize here, just use the VST transformed counts

correction = the mutliple test correction method to be done (BH=Benjamini-Hochberg)

```
In [26]:
          Maaslin2(
            input data = df input data2,
            input metadata = df input metadata2,
            output="./",
            min abundance = 0.01,
            min prevalence = 0.01,
            normalization = "NONE",
            transform = "NONE",
            analysis method = "LM",
            max significance = 0.25,
            random effects = c("sample name", "publication"),
            fixed effects = c("case"),
            correction="BH",
            standardize = TRUE,
            cores = 48,
            plot heatmap = TRUE,
            plot scatter = TRUE,
            heatmap first n = 100,
            reference=c("case,COVID19"))
```

```
[1] "Warning: Deleting existing log file: .//maaslin2.log"
2020-11-20 00:08:47 INFO::Writing function arguments to log file
2020-11-20 00:08:47 INFO::Verifying options selected are valid
2020-11-20 00:08:47 INFO::Determining format of input files
2020-11-20 00:08:47 INFO::Input format is data samples as rows and metadata samples as rows
2020-11-20 00:08:47 INFO::Formula for random effects: expr ~ (1 | sample_name) + (1 | publication)
2020-11-20 00:08:47 INFO::Formula for fixed effects: expr ~ case
```

2020-11-20 00:08:47 INFO::Filter data based on min abundance and min prevalence 2020-11-20 00:08:47 INFO::Total samples in data: 141

2020-11-20 00:08:47 INFO::Min samples required with min abundance for a feature not to be filtered: 1.410000

2020-11-20 00:08:47 INFO::Total filtered features: 13730

2020-11-20 00:08:47 INFO::Filtered feature names from abundance and prevalence filtering: GO.0045212.obsolete.neurotransm itter.receptor.biosynthetic.process, GO.0001319.obsolete.inheritance.of.oxidatively.modified.proteins.involved.in.replica tive.cell.aging, GO.1900008.obsolete.negative.regulation.of.extrachromosomal.rDNA.circle.accumulation.involved.in.replica tive.cell.aging, GO.0001302.obsolete.replicative.cell.aging, GO.0051704.multi.organism.process, GO.0051703.intraspecies.i nteraction.between.organisms, GO.0110148.biomineralization, GO.0043473.pigmentation, GO.0002376.immune.system.process, G 0.0044419.interspecies.interaction.between.organisms, G0.0048511.rhythmic.process, G0.0023052.signaling, G0.0007610.behav ior, GO.0015976.carbon.utilization, GO.0040011.locomotion, GO.0032502.developmental.process, GO.0032501.multicellular.org anismal.process, GO.0040007.growth, GO.0009758.carbohydrate.utilization, GO.0022610.biological.adhesion, GO.0022414.repro ductive.process, G0.0050896.response.to.stimulus, G0.0006791.sulfur.utilization, G0.0098754.detoxification, G0.0000003.re production, GO.0019740.nitrogen.utilization, GO.0008340.determination.of.adult.lifespan, GO.0019748.secondary.metabolic.p rocess, GO.0060384.innervation, GO.0022413.reproductive.process.in.single.celled.organism, GO.0009628.response.to.abioti c.stimulus, GO.0055114.oxidation.reduction.process, GO.0009791.post.embryonic.development, GO.0007585.respiratory.gaseou s.exchange.by.respiratory.system, GO.0008037.cell.recognition, GO.0009605.response.to.external.stimulus, GO.0009846.polle n.germination, GO.0043335.protein.unfolding, GO.0060033.anatomical.structure.regression, GO.0071722.detoxification.of.ars enic.containing.substance, GO.0032504.multicellular.organism.reproduction, GO.0000920.septum.digestion.after.cytokinesis, GO.0003006.developmental.process.involved.in.reproduction, GO.0045494.photoreceptor.cell.maintenance, GO.0001503.ossifica tion, GO.0007568.aging, GO.0030537.larval.behavior, GO.0097194.execution.phase.of.apoptosis, GO.0001906.cell.killing, GO. 0071840.cellular.component.organization.or.biogenesis, G0.0007017.microtubule.based.process, G0.0051702.interaction.with. symbiont, GO.0098727.maintenance.of.cell.number, GO.0002532.production.of.molecular.mediator.involved.in.inflammatory.res ponse, G0.0010312.detoxification.of.zinc.ion, G0.0014854.response.to.inactivity, G0.0022611.dormancy.process, G0.0009653. anatomical.structure.morphogenesis, GO.0009607.response.to.biotic.stimulus, GO.0007566.embryo.implantation, GO.0009566.fe rtilization, GO.0051775.response.to.redox.state, GO.0036268.swimming, GO.0009847.spore.germination, GO.0016049.cell.growt h, GO.0001775.cell.activation, GO.0033036.macromolecule.localization, GO.0045103.intermediate.filament.based.process, GO. 0019674.NAD.metabolic.process, GO.0002252.immune.effector.process, GO.0071684.organism.emergence.from.protective.structur e, GO.0045730.respiratory.burst, GO.0021700.developmental.maturation, GO.0098743.cell.aggregation, GO.0010073.meristem.ma intenance, GO.0051301.cell.division, GO.0048532.anatomical.structure.arrangement, GO.0008283.cell.population.proliferatio n, GO.0042221.response.to.chemical, GO.0061919.process.utilizing.autophagic.mechanism, GO.0022412.cellular.process.involv ed.in.reproduction.in.multicellular.organism, GO.0007155.cell.adhesion, GO.0043934.sporulation, GO.0035640.exploration.be havior, GO.0051606.detection.of.stimulus, GO.0048646.anatomical.structure.formation.involved.in.morphogenesis, GO.000763 1.feeding.behavior, GO.0048589.developmental.growth, GO.0007154.cell.communication, GO.0007049.cell.cycle, GO.0006955.imm une.response, GO.0007624.ultradian.rhythm, GO.0007163.establishment.or.maintenance.of.cell.polarity, GO.0022404.molting.c ycle.process, GO.0045058.T.cell.selection, GO.0006739.NADP.metabolic.process, GO.0044110.growth.involved.in.symbiotic.int eraction, GO.0042303.molting.cycle, GO.0032259.methylation, GO.0070085.glycosylation, GO.0007635.chemosensory.behavior, G 0.0061842.microtubule.organizing.center.localization, G0.0080190.lateral.growth, G0.0030534.adult.behavior, G0.0140253.ce ll.cell.fusion, GO.0030447.filamentous.growth, GO.0035176.social.behavior, GO.0048869.cellular.developmental.process, GO. 0007638.mechanosensory.behavior, G0.0032505.reproduction.of.a.single.celled.organism, G0.0050817.coagulation, G0.0051716. cellular.response.to.stimulus, GO.0030029.actin.filament.based.process, GO.0051641.cellular.localization, GO.0006276.plas mid.maintenance, GO.0006734.NADH.metabolic.process, GO.0014823.response.to.activity, GO.0032963.collagen.metabolic.proces s, GO.0009719.response.to.endogenous.stimulus, GO.0048856.anatomical.structure.development, GO.0019954.asexual.reproducti on, GO.0002440.production.of.molecular.mediator.of.immune.response, GO.0009405.pathogenesis, GO.0007059.chromosome.segreg ation, GO.0007389.pattern.specification.process, GO.0065009.regulation.of.molecular.function, GO.0030431.sleep, GO.009724 2.amyloid.beta.clearance, GO.0051189.prosthetic.group.metabolic.process, GO.0016203.muscle.attachment, GO.0065008.regulat ion.of.biological.quality, GO.0140029.exocytic.process, GO.0044703.multi.organism.reproductive.process, GO.0007272.enshea thment.of.neurons, GO.0090713.immunological.memory.process, GO.0035821.modulation.of.process.of.other.organism, GO.007098 8.demethylation, GO.0048771.tissue.remodeling, GO.0046034.ATP.metabolic.process, GO.0007340.acrosome.reaction, GO.199074

8.cellular.detoxification, GO.0022602.ovulation.cycle.process, GO.0071554.cell.wall.organization.or.biogenesis, GO.003219 6.transposition, GO.0016037.light.absorption, GO.0019882.antigen.processing.and.presentation, GO.0006928.movement.of.cel l.or.subcellular.component, GO.0002200.somatic.diversification.of.immune.receptors, GO.0022402.cell.cycle.process, GO.006 1687.detoxification.of.inorganic.compound, GO.0010022.meristem.determinacy, GO.0035637.multicellular.organismal.signalin g, G0.0022406.membrane.docking, G0.1902579.multi.organism.localization, G0.0048609.multicellular.organismal.reproductive. process, GO.0044706.multi.multicellular.organism.process, GO.0007622.rhythmic.behavior, GO.0008219.cell.death, GO.004806 6.developmental.pigmentation, GO.0002118.aggressive.behavior, GO.0007626.locomotory.behavior, GO.0044403.symbiotic.proces s, GO.0010127.mycothiol.dependent.detoxification, GO.0044764.multi.organism.cellular.process, GO.0014874.response.to.stim ulus.involved.in.regulation.of.muscle.adaptation, GO.0003008.system.process, GO.0042440.pigment.metabolic.process, GO.001 0118.stomatal.movement, G0.0019835.cytolysis, G0.0042330.taxis, G0.0006950.response.to.stress, G0.0009838.abscission, G0. 0007623.circadian.rhythm, GO.0009056.catabolic.process, GO.0009845.seed.germination, GO.0018933.nicotine.metabolic.proces s, G0.0006457.protein.folding, G0.0048870.cell.motility, G0.0010817.regulation.of.hormone.levels, G0.0048148.behavioral.r esponse.to.cocaine, GO.0045196.establishment.or.maintenance.of.neuroblast.polarity, GO.0046677.response.to.antibiotic, G 0.0001709.cell.fate.determination, G0.0006403.RNA.localization, G0.0072593.reactive.oxygen.species.metabolic.process, G0. 0003002.regionalization, G0.0035878.nail.development, G0.0120252.hydrocarbon.metabolic.process, G0.0003360.brainstem.deve lopment, G0.0048002.antigen.processing.and.presentation.of.peptide.antigen, G0.0044092.negative.regulation.of.molecular.f unction, GO.0009292.genetic.transfer, GO.0008356.asymmetric.cell.division, GO.0021670.lateral.ventricle.development, GO.0 030901.midbrain.development, G0.0048286.lung.alveolus.development, G0.0035107.appendage.morphogenesis, G0.0009877.nodulat ion, GO.0021508.floor.plate.formation, GO.0035902.response.to.immobilization.stress, GO.0018996.molting.cycle..collagen.a nd.cuticulin.based.cuticle, GO.0070314.G1.to.GO.transition, GO.0006081.cellular.aldehyde.metabolic.process, GO.0098869.ce llular.oxidant.detoxification, GO.0036342.post.anal.tail.morphogenesis, GO.0030010.establishment.of.cell.polarity, GO.009 8609.cell.cell.adhesion, GO.0061077.chaperone.mediated.protein.folding, GO.0001505.regulation.of.neurotransmitter.levels, GO.0050877.nervous.system.process, GO.0099402.plant.organ.development, GO.0071216.cellular.response.to.biotic.stimulus, G 0.0044282.small.molecule.catabolic.process, G0.0090659.walking.behavior, G0.0021794.thalamus.development, G0.0019883.anti gen.processing.and.presentation.of.endogenous.antigen, GO.0007569.cell.aging, GO.0001708.cell.fate.specification, GO.0090 693.plant.organ.senescence, GO.0009581.detection.of.external.stimulus, GO.0097502.mannosylation, GO.0044406.adhesion.of.s ymbiont.to.host, GO.0097485.neuron.projection.guidance, GO.0071852.fungal.type.cell.wall.organization.or.biogenesis, GO.0 051649.establishment.of.localization.in.cell, G0.0048583.regulation.of.response.to.stimulus, G0.0022600.digestive.system. process, GO.0043900.regulation.of.multi.organism.process, GO.0021984.adenohypophysis.development, GO.0001966.thigmotaxis, GO.0010228.vegetative.to.reproductive.phase.transition.of.meristem, GO.0061299.retina.vasculature.morphogenesis.in.camer a.type.eye, GO.0051304.chromosome.separation, GO.0061339.establishment.or.maintenance.of.monopolar.cell.polarity, GO.0032 964.collagen.biosynthetic.process, GO.0006766.vitamin.metabolic.process, GO.0000320.re.entry.into.mitotic.cell.cycle, GO. 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GO.0033223.2.aminoethylphosphonate.t

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of.vacuole.organization, GO.0006007.glucose.catabolic.process, GO.0045747.positive.regulation.of.Notch.signaling.pathway, GO.0072384.organelle.transport.along.microtubule, GO.0016598.protein.arginylation, GO.0009448.gamma.aminobutyric.acid.met abolic.process, GO.0046653.tetrahydrofolate.metabolic.process, GO.0032652.regulation.of.interleukin.1.production, GO.1902 280.regulation.of.RNA.helicase.activity, GO.0043029.T.cell.homeostasis, GO.0080144.amino.acid.homeostasis, GO.0034699.res ponse.to.luteinizing.hormone, GO.0000378.RNA.exon.ligation, GO.2000785.regulation.of.autophagosome.assembly, GO.0007616.l ong.term.memory, G0.0042278.purine.nucleoside.metabolic.process, G0.1903362.regulation.of.cellular.protein.catabolic.proc ess, GO.0019664.mixed.acid.fermentation, GO.0030417.nicotianamine.metabolic.process, GO.0036107.4.amino.4.deoxy.alpha.L.a rabinopyranosyl.undecaprenyl.phosphate.metabolic.process, GO.0046337.phosphatidylethanolamine.metabolic.process, GO.00069 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GO.0007269.neurotransmitter.secreti

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organization, GO.0006828.manganese.ion.transport, GO.0030509.BMP.signaling.pathway, GO.0045921.positive.regulation.of.exo cytosis, GO.0002686.negative.regulation.of.leukocyte.migration, GO.2000108.positive.regulation.of.leukocyte.apoptotic.pro cess, G0.0051023.regulation.of.immunoglobulin.secretion, G0.0006750.glutathione.biosynthetic.process, G0.0031103.axon.reg eneration, GO.0031506.cell.wall.glycoprotein.biosynthetic.process, GO.0002805.regulation.of.antimicrobial.peptide.biosynt hetic.process, GO.1901893.positive.regulation.of.cell.septum.assembly, GO.0075112.modulation.by.symbiont.of.host.transmem brane.receptor.mediated.signal.transduction, GO.0032695.negative.regulation.of.interleukin.12.production, GO.0030473.nucl ear.migration.along.microtubule, GO.2000401.regulation.of.lymphocyte.migration, GO.0009443.pyridoxal.5.phosphate.salvage, GO.0045836.positive.regulation.of.meiotic.nuclear.division, GO.0048013.ephrin.receptor.signaling.pathway, GO.0010863.posi 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RNA.import.into.mitochondrion, GO.0034635.glutathione.transport, GO.0032760.positive.regulation.of.tumor.necrosis.factor. production, GO.0006574.valine.catabolic.process, GO.0008090.retrograde.axonal.transport, GO.0006874.cellular.calcium.ion. homeostasis, GO.0046392.galactarate.catabolic.process, GO.0034551.mitochondrial.respiratory.chain.complex.III.assembly, G 0.0032309.icosanoid.secretion, G0.0060211.regulation.of.nuclear.transcribed.mRNA.poly.A..tail.shortening, G0.0045312.nor. spermidine.biosynthetic.process, GO.0010322.regulation.of.isopentenyl.diphosphate.biosynthetic.process..methylerythritol. 4.phosphate.pathway, G0.0051024.positive.regulation.of.immunoglobulin.secretion, G0.2001238.positive.regulation.of.extrin sic.apoptotic.signaling.pathway, GO.1903052.positive.regulation.of.proteolysis.involved.in.cellular.protein.catabolic.pro cess, GO.0046397.galacturonate.catabolic.process, GO.1903830.magnesium.ion.transmembrane.transport, GO.0090307.mitotic.sp indle.assembly, GO.0030683.mitigation.of.host.immune.response.by.virus, GO.1902801.regulation.of.heterochromatin.island.a ssembly, GO.0031112.positive.regulation.of.microtubule.polymerization.or.depolymerization, GO.0010923.negative.regulatio n.of.phosphatase.activity, GO.1900087.positive.regulation.of.G1.S.transition.of.mitotic.cell.cycle, GO.0010955.negative.r egulation.of.protein.processing, GO.0015908.fatty.acid.transport, GO.0006268.DNA.unwinding.involved.in.DNA.replication, G 0.0019605.butyrate.metabolic.process, G0.0001934.positive.regulation.of.protein.phosphorylation, G0.0018216.peptidyl.argi nine.methylation, GO.0051204.protein.insertion.into.mitochondrial.membrane, GO.0045582.positive.regulation.of.T.cell.diff erentiation, GO.0043666.regulation.of.phosphoprotein.phosphatase.activity, GO.0043096.purine.nucleobase.salvage, GO.19051 65.regulation.of.lysosomal.protein.catabolic.process, G0.0034136.negative.regulation.of.toll.like.receptor.2.signaling.pa thway, GO.2000213.positive.regulation.of.glutamate.metabolic.process, GO.0008616.queuosine.biosynthetic.process, GO.19038 95.negative.regulation.of.IRE1.mediated.unfolded.protein.response, G0.0034137.positive.regulation.of.toll.like.receptor. 2.signaling.pathway, G0.2000275.regulation.of.oxidative.phosphorylation.uncoupler.activity, G0.0030920.peptidyl.serine.ac etylation, G0.0090313.regulation.of.protein.targeting.to.membrane, G0.0006678.glucosylceramide.metabolic.process, G0.0009 158.ribonucleoside.monophosphate.catabolic.process, GO.0051919.positive.regulation.of.fibrinolysis, GO.0006560.proline.me tabolic.process, GO.0010952.positive.regulation.of.peptidase.activity, GO.0018095.protein.polyglutamylation, GO.0032305.p ositive.regulation.of.icosanoid.secretion, GO.0006147.guanine.catabolic.process, GO.0009095.aromatic.amino.acid.family.bi osynthetic.process..prephenate.pathway, GO.0051279.regulation.of.release.of.sequestered.calcium.ion.into.cytosol, GO.0015 677.copper.ion.import, GO.0043489.RNA.stabilization, GO.0036092.phosphatidylinositol.3.phosphate.biosynthetic.process, G 0.0032962.positive.regulation.of.inositol.trisphosphate.biosynthetic.process, GO.0046640.regulation.of.alpha.beta.T.cell. proliferation, GO.0065002.intracellular.protein.transmembrane.transport, GO.0045191.regulation.of.isotype.switching, GO.1 901068.guanosine.containing.compound.metabolic.process, GO.0071027.nuclear.RNA.surveillance, GO.0042573.retinoic.acid.met abolic.process, GO.0006273.lagging.strand.elongation, GO.0010882.regulation.of.cardiac.muscle.contraction.by.calcium.ion. signaling, GO.1900029.positive.regulation.of.ruffle.assembly, GO.0042351.de.novo.GDP.L.fucose.biosynthetic.process, GO.19 01380.negative.regulation.of.potassium.ion.transmembrane.transport, GO.1902101.positive.regulation.of.metaphase.anaphase. transition.of.cell.cycle, GO.2000171.negative.regulation.of.dendrite.development, GO.0030073.insulin.secretion, GO.004644 3.FAD.metabolic.process, GO.0050851.antigen.receptor.mediated.signaling.pathway, GO.0009067.aspartate.family.amino.acid.b iosynthetic.process, GO.0002092.positive.regulation.of.receptor.internalization, GO.0007141.male.meiosis.I, GO.0032210.re gulation.of.telomere.maintenance.via.telomerase, GO.0030174.regulation.of.DNA.dependent.DNA.replication.initiation, GO.00 90085.regulation.of.protein.deubiquitination, GO.0061014.positive.regulation.of.mRNA.catabolic.process, GO.0090277.positi ve.regulation.of.peptide.hormone.secretion, GO.0019381.atrazine.catabolic.process, GO.0000105.histidine.biosynthetic.proc ess, G0.0070072.vacuolar.proton.transporting.V.type.ATPase.complex.assembly, G0.0010466.negative.regulation.of.peptidase. activity, GO.0071421.manganese.ion.transmembrane.transport, GO.0042264.peptidyl.aspartic.acid.hydroxylation, GO.0046499. 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7955.glycerol.dehydrogenase..acceptor..activity, GO.0051537.2.iron..2.sulfur.cluster.binding, GO.0004984.olfactory.recept or.activity, GO.0034010.sulfolactate.sulfo.lyase.activity, GO.0046982.protein.heterodimerization.activity, GO.0008410.Co A.transferase.activity, GO.0098531.ligand.activated.transcription.factor.activity, GO.0009486.cytochrome.bo3.ubiquinol.ox idase.activity, G0.0005501.retinoid.binding, G0.0016799.hydrolase.activity..hydrolyzing.N.glycosyl.compounds, G0.0047809. 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10.16.5.38:8888/lab? 93/151

e.activity, GO.0018537.coenzyme.F420.dependent.N5.N10.methenyltetrahydromethanopterin.reductase.activity, GO.0004012.ATPa se.coupled.intramembrane.lipid.transporter.activity, G0.0016615.malate.dehydrogenase.activity, G0.0046978.TAP1.binding, G 0.0047470..1.4..alpha.D.glucan.1.alpha.D.glucosylmutase.activity, G0.0046507.UDPsulfoquinovose.synthase.activity, G0.0032 050.clathrin.heavy.chain.binding, GO.0051266.sirohydrochlorin.ferrochelatase.activity, GO.0016671.oxidoreductase.activit y..acting.on.a.sulfur.group.of.donors..disulfide.as.acceptor, GO.0008236.serine.type.peptidase.activity, GO.0033847.O.pho sphoserine.sulfhydrylase.activity, GO.0008428.ribonuclease.inhibitor.activity, GO.0008812.choline.dehydrogenase.activity, GO.0019210.kinase.inhibitor.activity, GO.0016778.diphosphotransferase.activity, GO.2001062.xylan.binding, GO.0005350.pyri midine.nucleobase.transmembrane.transporter.activity, G0.0033850.Z.farnesyl.diphosphate.synthase.activity, G0.0070061.fru ctose.binding, GO.0018551.hydrogensulfite.reductase.activity, GO.0045158.electron.transporter..transferring.electrons.wit hin.cytochrome.b6.f.complex.of.photosystem.II.activity, G0.0016868.intramolecular.transferase.activity..phosphotransferas es, GO.0016881.acid.amino.acid.ligase.activity, GO.0003713.transcription.coactivator.activity, GO.0050555.2.hydroxypropy 1.Com.lyase.activity, G0.0004175.endopeptidase.activity, G0.0098848.alpha.D.ribose.1.methylphosphonate.5.phosphate.C.P.ly ase.activity, GO.0016763.transferase.activity..transferring.pentosyl.groups, GO.0033558.protein.deacetylase.activity, GO. 0045545.syndecan.binding, GO.0061650.ubiquitin.like.protein.conjugating.enzyme.activity, GO.0046997.oxidoreductase.activi ty..acting.on.the.CH.NH.group.of.donors..flavin.as.acceptor, GO.0010521.telomerase.inhibitor.activity, GO.0052689.carboxy lic.ester.hydrolase.activity, GO.0008201.heparin.binding, GO.0016643.oxidoreductase.activity..acting.on.the.CH.NH2.group. of.donors..iron.sulfur.protein.as.acceptor, GO.0016823.hydrolase.activity..acting.on.acid.carbon.carbon.bonds..in.ketoni c.substances, GO.0055131.C3HC4.type.RING.finger.domain.binding, GO.2001065.mannan.binding, GO.0070205.2.succinyl.6.hydrox y.2.4.cyclohexadiene.1.carboxylate.synthase.activity, G0.0052381.tRNA.dimethylallyltransferase.activity, G0.0061799.cycli c.pyranopterin.monophosphate.synthase.activity, GO.0018849.muconate.cycloisomerase.activity, GO.0016812.hydrolase.activit y..acting.on.carbon.nitrogen..but.not.peptide..bonds..in.cyclic.amides, GO.0030975.thiamine.binding, GO.0030379.neurotens in.receptor.activity..non.G.protein.coupled, GO.0004075.biotin.carboxylase.activity, GO.0017151.DEAD.H.box.RNA.helicase.b inding, GO.0009882.blue.light.photoreceptor.activity, GO.0140034.methylation.dependent.protein.binding, GO.0035615.clathr in.adaptor.activity, GO.0043828.tRNA.2.selenouridine.synthase.activity, GO.0003866.3.phosphoshikimate.1.carboxyvinyltrans ferase.activity, GO.0009982.pseudouridine.synthase.activity, GO.0016166.phytoene.dehydrogenase.activity, GO.0008527.tast e.receptor.activity, GO.1902444.riboflavin.binding, GO.0043121.neurotrophin.binding, GO.0015399.primary.active.transmembr ane.transporter.activity, GO.0016703.oxidoreductase.activity..acting.on.single.donors.with.incorporation.of.molecular.oxy gen..incorporation.of.one.atom.of.oxygen..internal.monooxygenases.or.internal.mixed.function.oxidases., GO.0016421.CoA.ca rboxylase.activity, G0.0016776.phosphotransferase.activity..phosphate.group.as.acceptor, G0.2001070.starch.binding, G0.00 05372.water.transmembrane.transporter.activity, G0.0016882.cyclo.ligase.activity, G0.0019888.protein.phosphatase.regulato r.activity, G0.0030976.thiamine.pyrophosphate.binding, G0.0043199.sulfate.binding, G0.0016714.oxidoreductase.activity..ac ting.on.paired.donors..with.incorporation.or.reduction.of.molecular.oxygen..reduced.pteridine.as.one.donor..and.incorpora tion.of.one.atom.of.oxygen, GO.0140296.general.transcription.initiation.factor.binding, GO.0016742.hydroxymethyl...formy 1..and.related.transferase.activity, G0.0004494.methylmalonyl.CoA.mutase.activity, G0.0016716.oxidoreductase.activity..ac ting.on.paired.donors..with.incorporation.or.reduction.of.molecular.oxygen..another.compound.as.one.donor..and.incorporat ion.of.one.atom.of.oxygen, GO.0043210.alkanesulfonate.binding, GO.0005520.insulin.like.growth.factor.binding, GO.0036312. phosphatidylinositol.3.kinase.regulatory.subunit.binding, GO.0000286.alanine.dehydrogenase.activity, GO.0050371.tyrosine. phenol.lyase.activity, GO.0033737.1.pyrroline.dehydrogenase.activity, GO.0008066.glutamate.receptor.activity, GO.0005528. 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3.alcohol.dehydrogenase..cytochrome.c.L...activity, G0.0004420.hydroxymethylglutaryl.CoA.reductase..NADPH..activity, G0.0 008695.3.phenylpropionate.dioxygenase.activity, G0.0052736.beta.glucanase.activity, G0.0051377.mannose.ethanolamine.phosp hotransferase.activity, GO.0015645.fatty.acid.ligase.activity, GO.0047540.2.enoate.reductase.activity, GO.0050256.ribito 1.5.phosphate.2.dehydrogenase.activity, G0.0004018.N6..1.2.dicarboxyethyl.AMP.AMP.lyase..fumarate.forming..activity, G0.0 047372.acylglycerol.lipase.activity, G0.0050304.nitrous.oxide.reductase.activity, G0.0008946.oligonucleotidase.activity, GO.0050525.cutinase.activity, GO.0050263.ribosylpyrimidine.nucleosidase.activity, GO.0008912.lactaldehyde.reductase.acti vity, GO.0050641.6.methylsalicylic.acid.synthase.activity, GO.0004350.glutamate.5.semialdehyde.dehydrogenase.activity, G 0.0019180.dTDP.4.amino.4.6.dideoxygalactose.transaminase.activity, G0.0047435.5.guanidino.2.oxopentanoate.decarboxylase.a ctivity, G0.0008976.polyphosphate.kinase.activity, G0.0102155.S.sulfolactate.dehydrogenase.activity, G0.0004617.phosphogl ycerate.dehydrogenase.activity, GO.0032791.lead.ion.binding, GO.0002055.adenine.binding, GO.0052593.tryptamine.oxygen.oxi doreductase..deaminating..activity, GO.0047602.acetoacetate.decarboxylase.activity, GO.0000907.sulfonate.dioxygenase.acti vity, GO.0033812.3.oxoadipyl.CoA.thiolase.activity, GO.0052734.shikimate.3.dehydrogenase..NAD...activity, GO.0018545.NAD. 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GO.0004527.exonuclease.a

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008917.lipopolysaccharide.N.acetylglucosaminyltransferase.activity, G0.0090565.protein.phosphocysteine.mannitol.phosphotr ansferase.system.transporter.activity, GO.0010857.calcium.dependent.protein.kinase.activity, GO.0003730.mRNA.3.UTR.bindin g, G0.0000026.alpha.1.2.mannosyltransferase.activity, G0.0008893.guanosine.3.5.bis.diphosphate..3.diphosphatase.activity, GO.0008668..2.3.dihydroxybenzoyl.adenylate.synthase.activity, GO.0045129.NAD.independent.histone.deacetylase.activity, G 0.0102200.N.acetylphosphatidylethanolamine.hydrolysing.phospholipase.activity, G0.0005000.vasopressin.receptor.activity, GO.0016419.S.malonyltransferase.activity, GO.0080109.indole.3.acetonitrile.nitrile.hydratase.activity, GO.0008758.UDP.2. 3.diacylglucosamine.hydrolase.activity, GO.0008658.penicillin.binding, GO.0051991.UDP.N.acetyl.D.glucosamine.N.acetylmura moyl.L.alanyl.D.glutamyl.meso.2.6.diaminopimelyl.D.alanyl.D.alanine.diphosphoundecaprenol.4.beta.N.acetylglucosaminlytran sferase.activity, GO.0050164.oxoglutarate.dehydrogenase..NADP...activity, GO.0045322.unmethylated.CpG.binding, GO.000442 7.inorganic.diphosphatase.activity, GO.0003746.translation.elongation.factor.activity, GO.0008559.ATPase.coupled.xenobiot ic.transmembrane.transporter.activity, GO.0008753.NADPH.dehydrogenase..quinone..activity, GO.0050278.sedoheptulose.bispho sphatase.activity, GO.0008772..isocitrate.dehydrogenase..NADP....kinase.activity, GO.0022840.leak.channel.activity, GO.00 08843.endochitinase.activity, GO.0090554.phosphatidylcholine.floppase.activity, GO.0050380.undecaprenyl.diphosphatase.act ivity, GO.0031220.maltodextrin.phosphorylase.activity, GO.0035614.snRNA.stem.loop.binding, GO.0015416.ATPase.coupled.orga nic.phosphonate.transmembrane.transporter.activity, G0.0010420.3.4.dihydroxy.5.polyprenylbenzoic.acid.0.methyltransferas e.activity, GO.0043716.2.hydroxy.3.keto.5.methylthiopentenyl.1.phosphate.phosphatase.activity, GO.0004851.uroporphyrin.II I.C.methyltransferase.activity, 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GO.0052723.inositol.hexakisphosphate.1.kinase.activity, GO.0030623.U5.snRNA.binding, GO.0047023.androsterone.

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dehydrogenase.activity, GO.0042162.telomeric.DNA.binding, GO.0009007.site.specific.DNA.methyltransferase..adenine.specifi c..activity, G0.0015489.putrescine.transmembrane.transporter.activity, G0.0036009.protein.glutamine.N.methyltransferase.a ctivity, G0.0062037.D.loop.DNA.binding, G0.0047150.betaine.homocysteine.S.methyltransferase.activity, G0.0052654.L.leucin e.transaminase.activity, GO.0052740.1.acyl.2.lysophosphatidylserine.acylhydrolase.activity, GO.0035197.siRNA.binding, GO. 0061542.3.demethylubiquinol.n.3.0.methyltransferase.activity, G0.0016212.kynurenine.oxoglutarate.transaminase.activity, G 0.0008174.mRNA.methyltransferase.activity, G0.0004356.glutamate.ammonia.ligase.activity, G0.0005151.interleukin.1..type.I I.receptor.binding, GO.0042931.enterobactin.transmembrane.transporter.activity, GO.0034450.ubiquitin.ubiquitin.ligase.act ivity, G0.0008495.protoheme.IX.farnesyltransferase.activity, G0.0030145.manganese.ion.binding, G0.0070009.serine.type.ami nopeptidase.activity, 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6.NAD.dependent.histone.deacetylase.activity, GO.0070856.myosin.VI.light.chain.binding, GO.0035198.miRNA.binding, GO.0034 648.histone.demethylase.activity..H3.dimethyl.K4.specific., G0.0033914.xylan.1.3.beta.xylosidase.activity, G0.0032217.rib oflavin.transmembrane.transporter.activity, GO.0004712.protein.serine.threonine.tyrosine.kinase.activity, GO.0015553.xant hosine.transmembrane.transporter.activity, GO.0008119.thiopurine.S.methyltransferase.activity, GO.0052726.inositol.1.3.4. trisphosphate.5.kinase.activity, GO.0000033.alpha.1.3.mannosyltransferase.activity, GO.0030580.quinone.cofactor.methyltra nsferase.activity, G0.0042054.histone.methyltransferase.activity, G0.0008252.nucleotidase.activity, G0.0015146.pentose.tr ansmembrane.transporter.activity, GO.0008967.phosphoglycolate.phosphatase.activity, GO.0008715.CDP.diacylglycerol.diphosp hatase.activity, GO.0080101.phosphatidyl.N.dimethylethanolamine.N.methyltransferase.activity, GO.0004550.nucleoside.dipho sphate.kinase.activity, G0.0005052.peroxisome.matrix.targeting.signal.1.binding, G0.0044603.protein.adenylylhydrolase.act ivity, GO.0016509.long.chain.3.hydroxyacyl.CoA.dehydrogenase.activity, GO.0061603.molybdenum.cofactor.guanylyltransferas e.activity, GO.0008878.glucose.1.phosphate.adenylyltransferase.activity, GO.0004315.3.oxoacyl..acyl.carrier.protein..synt hase.activity, G0.0047451.3.hydroxyoctanoyl..acyl.carrier.protein..dehydratase.activity, G0.0008984.protein.glutamate.met hylesterase.activity, GO.0071160.cyanophycin.synthetase.activity..L.aspartate.adding., GO.0046406.magnesium.protoporphyri n.IX.methyltransferase.activity, GO.0070180.large.ribosomal.subunit.rRNA.binding, GO.0047045.testosterone.17.beta.dehydro genase..NADP...activity, GO.0046537.2.3.bisphosphoglycerate.independent.phosphoglycerate.mutase.activity, GO.0090585.prot ein.phosphocysteine.L.ascorbate.phosphotransferase.system.transporter.activity, GO.0080130.L.phenylalanine.2.oxoglutarat e.aminotransferase.activity, GO.0032554.purine.deoxyribonucleotide.binding, GO.0033736.L.lysine.6.oxidase.activity, GO.00 08106.alcohol.dehydrogenase..NADP...activity, GO.0008908.isochorismatase.activity, GO.0047325.inositol.tetrakisphosphate. 1.kinase.activity, G0.0050269.coniferyl.aldehyde.dehydrogenase.activity, G0.0052724.inositol.hexakisphosphate.3.kinase.ac tivity, GO.0140394.ATPase.coupled.azole.transmembrane.transporter.activity, GO.0050640.isopenicillin.N.N.acyltransferase. activity, GO.0008160.protein.tyrosine.phosphatase.activator.activity, GO.0000773.phosphatidyl.N.methylethanolamine.N.meth yltransferase.activity, GO.0003980.UDP.glucose.glycoprotein.glucosyltransferase.activity, GO.0005368.taurine.transmembran e.transporter.activity, GO.0047679.arginine.racemase.activity, GO.0015666.restriction.endodeoxyribonuclease.activity, GO. 0052717.tRNA.specific.adenosine.34.deaminase.activity, G0.0033723.fluoroacetaldehyde.dehydrogenase.activity, G0.0015407.A TPase.coupled.monosaccharide.transmembrane.transporter.activity, G0.0008689.3.demethylubiquinone.9.3.0.methyltransferase. activity, GO.0004709.MAP.kinase.kinase.kinase.activity, GO.0034069.aminoglycoside.N.acetyltransferase.activity, GO.003316 4.glycolipid.6.alpha.mannosyltransferase.activity, GO.0015591.D.ribose.transmembrane.transporter.activity, GO.0003968.RN A.directed.5.3.RNA.polymerase.activity, GO.0016888.endodeoxyribonuclease.activity..producing.5.phosphomonoesters, GO.0050 308.sugar.phosphatase.activity, G0.0071077.adenosine.3.5.bisphosphate.transmembrane.transporter.activity, G0.0032266.phos phatidylinositol.3.phosphate.binding, G0.0032041.NAD.dependent.histone.deacetylase.activity..H3.K14.specific., G0.000853 4.oxidized.purine.nucleobase.lesion.DNA.N.glycosylase.activity, GO.0043027.cysteine.type.endopeptidase.inhibitor.activit y.involved.in.apoptotic.process, GO.0015514.nitrite.efflux.transmembrane.transporter.activity, GO.0016423.tRNA..guanine.. methyltransferase.activity, GO.1904593.prostaglandin.binding, GO.0008490.arsenite.secondary.active.transmembrane.transpor ter.activity, GO.0043225.ATPase.coupled.inorganic.anion.transmembrane.transporter.activity, GO.0050133.N6.hydroxylysine. 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ogenase.activity..zinc.dependent, GO.0003841.1.acylglycerol.3.phosphate.O.acyltransferase.activity, GO.0004656.procollage n.proline.4.dioxygenase.activity, G0.0008870.galactoside.0.acetyltransferase.activity, G0.0004362.glutathione.disulfide.r eductase.activity, G0.0048256.flap.endonuclease.activity, G0.0004697.protein.kinase.C.activity, G0.0015019.heparan.alpha. glucosaminide.N.acetyltransferase.activity, GO.0004385.guanylate.kinase.activity, GO.0004032.alditol.NADP..1.oxidoreducta se.activity, G0.0044769.ATPase.activity..coupled.to.transmembrane.movement.of.ions..rotational.mechanism, G0.0004149.dihy drolipoyllysine.residue.succinyltransferase.activity, G0.0004651.polynucleotide.5.phosphatase.activity, G0.0008706.6.phos pho.beta.glucosidase.activity, GO.0047158.sinapoylglucose.sinapoylglucose.O.sinapoyltransferase.activity, GO.0047693.ATP. diphosphatase.activity, GO.0005244.voltage.gated.ion.channel.activity, GO.0017005.3.tyrosyl.DNA.phosphodiesterase.activit y, GO.0004781.sulfate.adenylyltransferase..ATP..activity, GO.0004683.calmodulin.dependent.protein.kinase.activity, GO.005 2795.exo.alpha..2..6..sialidase.activity, GO.0031405.lipoic.acid.binding, GO.0052925.dol.P.Man.Man.5.GlcNAc.2..PP.Dol.alp ha.1.3.mannosyltransferase.activity, GO.0008107.galactoside.2.alpha.L.fucosyltransferase.activity, GO.0004995.tachykinin. receptor.activity, GO.0004693.cyclin.dependent.protein.serine.threonine.kinase.activity, GO.0004558.alpha.1.4.glucosidas e.activity, GO.0015079.potassium.ion.transmembrane.transporter.activity, GO.1990238.double.stranded.DNA.endodeoxyribonucl ease.activity, G0.0097063.cadmium.ion.sensor.activity, G0.0047381.dodecanoyl..acyl.carrier.protein..hydrolase.activity, G 0.0004377.GDP.Man.Man3GlcNAc2.PP.Dol.alpha.1.2.mannosyltransferase.activity, G0.0004715.non.membrane.spanning.protein.tyr osine.kinase.activity, GO.0043733.DNA.3.methylbase.glycosylase.activity, GO.0008536.Ran.GTPase.binding, GO.1903135.cupri c.ion.binding, GO.0046990.N.hydroxyarylamine.O.acetyltransferase.activity, GO.0004861.cyclin.dependent.protein.serine.thr eonine.kinase.inhibitor.activity, GO.0004017.adenylate.kinase.activity, GO.0009041.uridylate.kinase.activity, GO.0008137. NADH.dehydrogenase..ubiquinone..activity, GO.0015153.rhamnose.transmembrane.transporter.activity, GO.0015595.ATPase.coupl ed.spermidine.transmembrane.transporter.activity, G0.0008744.L.xylulokinase.activity, G0.0008666.2.3.4.5.tetrahydropyridi ne.2.6.dicarboxylate.N.succinyltransferase.activity, G0.0005225.volume.sensitive.anion.channel.activity, G0.0004340.gluco kinase.activity, G0.0004025.alcohol.dehydrogenase.activity..iron.dependent, G0.0004482.mRNA..guanine.N7...methyltransfera se.activity, GO.0009046.zinc.D.Ala.D.Ala.carboxypeptidase.activity, GO.0030378.serine.racemase.activity, GO.0000701.purin e.specific.mismatch.base.pair.DNA.N.glycosylase.activity, G0.0042973.glucan.endo.1.3.beta.D.glucosidase.activity, G0.0090 600.alpha.1.3.glucosidase.activity, GO.0050061.long.chain.aldehyde.dehydrogenase.activity, GO.0016435.rRNA..guanine..meth yltransferase.activity, GO.0015441.ATPase.coupled.beta.glucan.transporter.activity, GO.0080041.ADP.ribose.pyrophosphohydr olase.activity, GO.0016492.G.protein.coupled.neurotensin.receptor.activity, GO.0035529.NADH.pyrophosphatase.activity, GO. 0015226.carnitine.transmembrane.transporter.activity, GO.0001632.leukotriene.B4.receptor.activity, GO.0008240.tripeptidy 1.peptidase.activity, GO.0052591.sn.glycerol.3.phosphate.ubiquinone.8.oxidoreductase.activity, GO.0004805.trehalose.phosp hatase.activity, G0.0004059.aralkylamine.N.acetyltransferase.activity, G0.0004849.uridine.kinase.activity, G0.0016427.tRN A...cytosine..methyltransferase.activity, GO.0042960.antimonite.secondary.active.transmembrane.transporter.activity, GO.00 03870.5.aminolevulinate.synthase.activity, G0.0000014.single.stranded.DNA.endodeoxyribonuclease.activity, G0.0004113.2.3. cyclic.nucleotide.3.phosphodiesterase.activity, G0.0030971.receptor.tyrosine.kinase.binding, G0.0042900.arabinose.transme mbrane.transporter.activity, GO.0032559.adenyl.ribonucleotide.binding, GO.0004687.myosin.light.chain.kinase.activity, GO. 0008271.secondary.active.sulfate.transmembrane.transporter.activity, G0.0044212.transcription.regulatory.region.sequence. specific.DNA.binding, GO.0033947.mannosylglycoprotein.endo.beta.mannosidase.activity, GO.0052692.raffinose.alpha.galactos idase.activity, GO.0008441.3.2..5.bisphosphate.nucleotidase.activity, GO.0004381.fucosylgalactoside.3.alpha.galactosyltra nsferase.activity, GO.0052743.inositol.tetrakisphosphate.phosphatase.activity, GO.0003983.UTP.glucose.1.phosphate.uridyly ltransferase.activity, GO.0009001.serine.O.acetyltransferase.activity, GO.0004844.uracil.DNA.N.glycosylase.activity, GO.0 008881.glutamate.racemase.activity, GO.0102391.decanoate.CoA.ligase.activity, GO.0018392.glycoprotein.3.alpha.L.fucosyltr ansferase.activity, GO.0008925.maltose.O.acetyltransferase.activity, GO.0034212.peptide.N.acetyltransferase.activity, GO. 0015095.magnesium.ion.transmembrane.transporter.activity, G0.0004983.neuropeptide.Y.receptor.activity, G0.0047200.tetrahy drodipicolinate.N.acetyltransferase.activity, GO.0051734.ATP.dependent.polynucleotide.kinase.activity, GO.0015418.ATPase. coupled.quaternary.ammonium.compound.transmembrane.transporting.activity, GO.0016891.endoribonuclease.activity..producin g.5.phosphomonoesters, GO.0015440.ATPase.coupled.peptide.transmembrane.transporter.activity, GO.0031217.glucan.1.4.beta.g lucosidase.activity, GO.0004001.adenosine.kinase.activity, GO.1902936.phosphatidylinositol.bisphosphate.binding, GO.00047 14.transmembrane.receptor.protein.tyrosine.kinase.activity, G0.0000155.phosphorelay.sensor.kinase.activity, G0.0016896.ex oribonuclease.activity..producing.5.phosphomonoesters, GO.0000182.rDNA.binding, GO.0047513.1.2.alpha.L.fucosidase.activit v, GO.0016300.tRNA..uracil..methyltransferase.activity, GO.0034480.phosphatidylcholine.phospholipase.C.activity, GO.00047

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07.MAP.kinase.activity, G0.0003899.DNA.directed.5.3.RNA.polymerase.activity, G0.0051392.tRNA.N.acetyltransferase.activit y, GO.0004708.MAP.kinase.kinase.activity, GO.0016279.protein.lysine.N.methyltransferase.activity, GO.0004690.cyclic.nucle otide.dependent.protein.kinase.activity, GO.0050406..acetyl.CoA.carboxylase..phosphatase.activity, GO.0015276.ligand.gate d.ion.channel.activity, GO.0008921.lipopolysaccharide.1.6.galactosyltransferase.activity, GO.0019158.mannokinase.activit y, GO.0003688.DNA.replication.origin.binding, GO.0001642.group.III.metabotropic.glutamate.receptor.activity, GO.0016760.c ellulose.synthase..UDP.forming..activity, GO.0052757.chondroitin.hydrolase.activity, GO.0009931.calcium.dependent.protei n.serine.threonine.kinase.activity, GO.0022869.protein.N.PI..phosphohistidine.lactose.phosphotransferase.system.transport er.activity, GO.0008138.protein.tyrosine.serine.threonine.phosphatase.activity, GO.0004574.oligo.1.6.glucosidase.activit y, 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GO.0047035.testosterone.dehydrogenase..NAD...activity, GO.0008928.mannose.1.phosphate.guanylyltr ansferase...GDP..activity, GO.0000976.transcription.regulatory.region.sequence.specific.DNA.binding, GO.0004675.transmembr ane.receptor.protein.serine.threonine.kinase.activity, G0.0008791.arginine.N.succinyltransferase.activity, G0.0016290.pal mitoyl.CoA.hydrolase.activity, GO.0032558.adenyl.deoxyribonucleotide.binding, GO.0050569.glycolaldehyde.dehydrogenase.act ivity, G0.0047689.aspartate.racemase.activity, G0.0008120.ceramide.glucosyltransferase.activity, G0.0071972.peptidoglyca n.L.D.transpeptidase.activity, GO.0008564.protein.exporting.ATPase.activity, GO.0099122.RNA.polymerase.II.C.terminal.doma in.binding, GO.0004483.mRNA..nucleoside.2.0...methyltransferase.activity, GO.0015085.calcium.ion.transmembrane.transporte r.activity, GO.0047334.diphosphate.fructose.6.phosphate.1.phosphotransferase.activity, GO.0050176.phenylalanine.N.acetylt ransferase.activity, 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o.7.8.dihydroguanosine.triphosphate.pyrophosphatase.activity, GO.0015217.ADP.transmembrane.transporter.activity, GO.00046

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62.CAAX.protein.geranylgeranyltransferase.activity, G0.0034593.phosphatidylinositol.bisphosphate.phosphatase.activity, G 0.0004042.acetyl.CoA.L.glutamate.N.acetyltransferase.activity, G0.0004475.mannose.1.phosphate.guanylyltransferase.activit y, G0.0004135.amylo.alpha.1.6.glucosidase.activity, G0.0050302.indole.3.acetaldehyde.oxidase.activity, G0.0031708.endothe lin.B.receptor.binding, GO.0008198.ferrous.iron.binding, GO.0000774.adenyl.nucleotide.exchange.factor.activity, GO.000168 1.sialate.O.acetylesterase.activity, GO.0008193.tRNA.guanylyltransferase.activity, GO.0046027.phospholipid.diacylglycero l.acyltransferase.activity, GO.0047259.glucomannan.4.beta.mannosyltransferase.activity, GO.0015081.sodium.ion.transmembra ne.transporter.activity, GO.0034046.poly.G..binding, GO.0035381.ATP.gated.ion.channel.activity, GO.0003774.motor.activit y, G0.0004862.cAMP.dependent.protein.kinase.inhibitor.activity, G0.0008662.1.phosphofructokinase.activity, G0.0005354.gal 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GO.0015199.amino.acid.betaine.transmembrane.transporter.activity, GO.19012

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36.4..trimethylammonio.butanoate.transmembrane.transporter.activity, GO.0015481.maltose.transporting.porin.activity, GO.0 016906.sterol.3.beta.glucosyltransferase.activity, G0.0015148.D.xylose.transmembrane.transporter.activity, G0.0046030.ino sitol.trisphosphate.phosphatase.activity, G0.0003934.GTP.cyclohydrolase.I.activity, G0.0061821.telomeric.D.loop.binding, GO.0015301.anion.anion.antiporter.activity, GO.0004378.GDP.Man.Man1GlcNAc2.PP.Dol.alpha.1.3.mannosyltransferase.activit y, GO.0047265.poly.glycerol.phosphate..alpha.glucosyltransferase.activity, GO.0016531.copper.chaperone.activity, GO.00038 73.6.phosphofructo.2.kinase.activity, GO.0008837.diaminopimelate.epimerase.activity, GO.0070273.phosphatidylinositol.4.ph osphate.binding, G0.0052821.DNA.7.methyladenine.glycosylase.activity, G0.0046915.transition.metal.ion.transmembrane.trans porter.activity, GO.0004725.protein.tyrosine.phosphatase.activity, GO.0008143.poly.A..binding, GO.0008028.monocarboxylic. 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A.binding, GO.0008311.double.stranded.DNA.3.5.exodeoxyribonuclease.activity, GO.0001165.RNA.polymerase.I.cis.regulatory.r egion.sequence.specific.DNA.binding, GO.0015128.gluconate.transmembrane.transporter.activity, GO.0015141.succinate.transm embrane.transporter.activity, GO.0005229.intracellular.calcium.activated.chloride.channel.activity, GO.0046975.histone.me thyltransferase.activity..H3.K36.specific., G0.0015413.ATPase.coupled.nickel.transmembrane.transporter.activity, G0.00438 65.methionine.transmembrane.transporter.activity, G0.0015506.nucleoside.proton.symporter.activity, G0.1990189.peptide.ser ine.N.acetyltransferase.activity, GO.0004003.DNA.helicase.activity, GO.0052915.23S.rRNA..guanine.2445..N.2...methyltransf erase.activity, GO.0000980.RNA.polymerase.II.cis.regulatory.region.sequence.specific.DNA.binding, GO.0061994.ATP.dependen t.protein.nucleic.acid.complex.displacement.activity, GO.0005304.L.valine.transmembrane.transporter.activity, GO.0015425. ATPase.coupled.nonpolar.amino.acid.transporter.activity, GO.0043682.copper.transmembrane.transporter.activity..phosphoryl ative.mechanism, GO.0022824.transmitter.gated.ion.channel.activity, GO.0052929.ATP.3.cytidine.cytidine.tRNA.adenylyltrans ferase.activity, GO.0005343.organic.acid.sodium.symporter.activity, GO.0046961.proton.transporting.ATPase.activity..rotat ional.mechanism, GO.0061505.DNA.topoisomerase.type.II..double.strand.cut..ATP.hydrolyzing..activity, GO.0003918.DNA.topoi somerase.type.II..double.strand.cut..ATP.hydrolyzing..activity, GO.0008574.ATP.dependent.microtubule.motor.activity..plu s.end.directed, GO.0086038.calcium.sodium.antiporter.activity.involved.in.regulation.of.cardiac.muscle.cell.membrane.pote ntial, G0.0008332.low.voltage.gated.calcium.channel.activity, G0.0009675.high.affinity.sulfate.proton.symporter.activity, GO.0022851.GABA.gated.chloride.ion.channel.activity, GO.0033682.5.3.DNA.RNA.helicase.activity, GO.0061995.ATP.dependent.p rotein.DNA.complex.displacement.activity, GO.0004931.extracellularly.ATP.gated.cation.channel.activity, GO.0015518.arabin ose.proton.symporter.activity, GO.0035497.cAMP.response.element.binding, GO.0061749.forked.DNA.dependent.helicase.activit y, G0.0009679.hexose.proton.symporter.activity, G0.0016933.extracellularly.glycine.gated.ion.channel.activity, G0.001519 1.L.methionine.transmembrane.transporter.activity, G0.0008273.calcium.potassium.sodium.antiporter.activity, G0.0005291.h igh.affinity.L.histidine.transmembrane.transporter.activity, GO.0005283.amino.acid.sodium.symporter.activity, GO.0015378. sodium.chloride.symporter.activity, GO.0008331.high.voltage.gated.calcium.channel.activity, GO.0015278.calcium.release.ch annel.activity, GO.0034335.DNA.negative.supercoiling.activity, GO.0043142.single.stranded.DNA.helicase.activity, GO.00429 45.D.serine.transmembrane.transporter.activity, G0.0015271.outward.rectifier.potassium.channel.activity, G0.0004970.ionot ropic.glutamate.receptor.activity, GO.0008507.sodium.iodide.symporter.activity, GO.1904315.transmitter.gated.ion.channel. activity.involved.in.regulation.of.postsynaptic.membrane.potential, GO.0043138.3.5.DNA.helicase.activity, GO.0015649.2.ke to.3.deoxygluconate.proton.symporter.activity, GO.0033676.double.stranded.DNA.helicase.activity, GO.0008569.ATP.dependen t.microtubule.motor.activity..minus.end.directed, GO.0005222.intracellular.cAMP.activated.cation.channel.activity, GO.000 1006.RNA.polymerase.III.type.3.promoter.sequence.specific.DNA.binding, GO.0140161.monocarboxylate.sodium.symporter.activi ty, GO.0001002.RNA.polymerase.III.type.1.promoter.sequence.specific.DNA.binding, GO.0048474.D.methionine.transmembrane.tr ansporter.activity, GO.0034056.estrogen.response.element.binding, GO.0017116.single.stranded.DNA.helicase.activity, GO.00 15528.lactose.proton.symporter.activity, GO.0033230.ATPase.coupled.cysteine.transmembrane.transporter.activity, GO.001538 5.sodium.proton.antiporter.activity, G0.0061459.L.arginine.transmembrane.transporter.activity, G0.0017153.sodium.dicarbox ylate.symporter.activity, GO.0043141.5.3.DNA.helicase.activity, GO.0003689.DNA.clamp.loader.activity, GO.0015496.putresci ne.ornithine.antiporter.activity, GO.0010485.H4.histone.acetyltransferase.activity, GO.0086008.voltage.gated.potassium.ch annel.activity.involved.in.cardiac.muscle.cell.action.potential.repolarization, GO.0043140.3.5.DNA.helicase.activity, GO. 0043998.H2A.histone.acetyltransferase.activity, G0.0051978.lysophospholipid.sodium.symporter.activity, G0.0015386.potassi um.proton.antiporter.activity, GO.0015369.calcium.proton.antiporter.activity, GO.0015341.zinc.efflux.active.transmembran e.transporter.activity, GO.0015565.threonine.efflux.transmembrane.transporter.activity, GO.0036042.long.chain.fatty.acyl. CoA.binding, GO.0005300.high.affinity.tryptophan.transmembrane.transporter.activity, GO.0008900.potassium.proton.exchangi ng.ATPase.activity, GO.0015408.ATPase.coupled.ferric.iron.transmembrane.transporter.activity, GO.0005242.inward.rectifie r.potassium.channel.activity, GO.0015366.malate.proton.symporter.activity, GO.0034459.3.5.RNA.helicase.activity, GO.00156 61.L.lysine.efflux.transmembrane.transporter.activity, G0.0034458.3.5.RNA.helicase.activity, G0.0005223.intracellular.cGM P.activated.cation.channel.activity, GO.0016286.small.conductance.calcium.activated.potassium.channel.activity, GO.007088 8.E.box.binding, GO.0043858.arginine.ornithine.antiporter.activity, GO.0001003.RNA.polymerase.III.type.2.promoter.sequenc e.specific.DNA.binding, GO.0008551.cadmium.transmembrane.transporter.activity..phosphorylative.mechanism, GO.0009378.fou r.way.junction.helicase.activity, GO.0043995.histone.acetyltransferase.activity..H4.K5.specific., GO.0015655.alanine.sodi um.symporter.activity, GO.0005298.proline.sodium.symporter.activity, GO.0008508.bile.acid.sodium.symporter.activity, GO.0 043996.histone.acetyltransferase.activity..H4.K8.specific., G0.0015517.galactose.proton.symporter.activity, G0.0048763.ca

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lcium.induced.calcium.release.activity, GO.0005219.ryanodine.sensitive.calcium.release.channel.activity, GO.0005295.neutr al.amino.acid.sodium.symporter.activity, GO.0044668.sodium.malonate.symporter.activity, GO.0005220.inositol.1.4.5.trispho sphate.sensitive.calcium.release.channel.activity, GO.0046972.histone.acetyltransferase.activity..H4.K16.specific., GO.00 08511.sodium.potassium.chloride.symporter.activity, G0.0015501.glutamate.sodium.symporter.activity, G0.0000102.L.methioni ne.secondary.active.transmembrane.transporter.activity, G0.0022848.acetylcholine.gated.cation.selective.channel.activity, GO.0015535.fucose.proton.symporter.activity, GO.0016934.extracellularly.glycine.gated.chloride.channel.activity 2020-11-20 00:08:48 INFO::Running selected normalization method: NONE 2020-11-20 00:08:48 INFO::Total filtered features with variance filtering: 0 2020-11-20 00:08:48 INFO::Filtered feature names from variance filtering: 2020-11-20 00:08:48 INFO::Applying z-score to standardize continuous metadata 2020-11-20 00:08:48 INFO::Running selected transform method: NONE 2020-11-20 00:08:48 INFO::Running selected analysis method: LM 2020-11-20 00:08:48 INFO::Creating cluster of 48 R processes 2020-11-20 00:09:50 INFO::Counting total values for each feature 2020-11-20 00:09:50 WARNING::Deleting existing residuals file: .//residuals.rds 2020-11-20 00:09:50 INFO::Writing residuals to file .//residuals.rds 2020-11-20 00:09:50 INFO::Writing all results to file (ordered by increasing q-values): .//all results.tsv 2020-11-20 00:09:50 INFO::Writing the significant results (those which are less than or equal to the threshold of 0.25000 0) to file (ordered by increasing q-values): .//significant results.tsv 2020-11-20 00:09:50 INFO::Writing heatmap of significant results to file: .//heatmap.pdf 2020-11-20 00:09:51 INFO::Writing association plots (one for each significant association) to output folder: ./ 2020-11-20 00:09:51 INFO::Plotting associations from most to least significant, grouped by metadata 2020-11-20 00:09:51 INFO::Plotting data for metadata number 1, case 2020-11-20 00:09:51 INFO::Creating boxplot for categorical data, case vs GO.0034660.ncRNA.metabolic.process 2020-11-20 00:09:51 INFO::Creating boxplot for categorical data, case vs GO.0016740.transferase.activity 2020-11-20 00:09:51 INFO::Creating boxplot for categorical data, case vs GO.0140098.catalytic.activity..acting.on.RNA 2020-11-20 00:09:51 INFO::Creating boxplot for categorical data, case vs GO.0043170.macromolecule.metabolic.process 2020-11-20 00:09:51 INFO::Creating boxplot for categorical data, case vs GO.0016070.RNA.metabolic.process 2020-11-20 00:09:52 INFO::Creating boxplot for categorical data, case vs GO.0019538.protein.metabolic.process 2020-11-20 00:09:52 INFO::Creating boxplot for categorical data, case vs GO.0016740.transferase.activity 2020-11-20 00:09:52 INFO::Creating boxplot for categorical data, case vs GO.0043168.anion.binding 2020-11-20 00:09:52 INFO::Creating boxplot for categorical data, case vs GO.1901362.organic.cyclic.compound.biosynthetic. process 2020-11-20 00:09:52 INFO::Creating boxplot for categorical data, case vs GO.0044260.cellular.macromolecule.metabolic.proc 2020-11-20 00:09:52 INFO::Creating boxplot for categorical data, case vs GO.0003676.nucleic.acid.binding 2020-11-20 00:09:52 INFO::Creating boxplot for categorical data, case vs GO.0065007.biological.regulation 2020-11-20 00:09:53 INFO::Creating boxplot for categorical data, case vs GO.0003677.DNA.binding 2020-11-20 00:09:53 INFO::Creating boxplot for categorical data, case vs GO.0016772.transferase.activity..transferring.ph osphorus.containing.groups 2020-11-20 00:09:53 INFO::Creating boxplot for categorical data, case vs GO.0009987.cellular.process 2020-11-20 00:09:53 INFO::Creating boxplot for categorical data, case vs G0.0050794.regulation.of.cellular.process 2020-11-20 00:09:53 INFO::Creating boxplot for categorical data, case vs G0.0090304.nucleic.acid.metabolic.process 2020-11-20 00:09:53 INFO::Creating boxplot for categorical data, case vs G0.0050789.regulation.of.biological.process 2020-11-20 00:09:53 INFO::Creating boxplot for categorical data, case vs GO.0044260.cellular.macromolecule.metabolic.proc ess 2020-11-20 00:09:54 INFO::Creating boxplot for categorical data, case vs GO.0016829.lyase.activity 2020-11-20 00:09:54 INFO::Creating boxplot for categorical data, case vs GO.0016779.nucleotidyltransferase.activity 2020-11-20 00:09:54 INFO::Creating boxplot for categorical data, case vs GO.0034645.cellular.macromolecule.biosynthetic.p

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rocess
2020-11-20 00:09:54 INFO::Creating boxplot for categorical data, case vs GO.0044281.small.molecule.metabolic.process
2020-11-20 00:09:54 INFO::Creating boxplot for categorical data, case vs GO.0044283.small.molecule.biosynthetic.process
2020-11-20 00:09:54 INFO::Creating boxplot for categorical data, case vs GO.0009987.cellular.process
2020-11-20 00:09:54 INFO::Creating boxplot for categorical data, case vs GO.0009059.macromolecule.biosynthetic.process
2020-11-20 00:09:55 INFO::Creating boxplot for categorical data, case vs GO.0019438.aromatic.compound.biosynthetic.proces
2020-11-20 00:09:55 INFO::Creating boxplot for categorical data, case vs GO.0044262.cellular.carbohydrate.metabolic.proce
2020-11-20 00:09:55 INFO::Creating boxplot for categorical data, case vs GO.0019438.aromatic.compound.biosynthetic.proces
2020-11-20 00:09:55 INFO::Creating boxplot for categorical data, case vs GO.1901566.organonitrogen.compound.biosynthetic.
process
2020-11-20 00:09:55 INFO::Creating boxplot for categorical data, case vs GO.0006139.nucleobase.containing.compound.metabo
2020-11-20 00:09:55 INFO::Creating boxplot for categorical data, case vs GO.0043168.anion.binding
2020-11-20 00:09:56 INFO::Creating boxplot for categorical data, case vs GO.0034641.cellular.nitrogen.compound.metabolic.
process
2020-11-20 00:09:56 INFO::Creating boxplot for categorical data, case vs GO.0006793.phosphorus.metabolic.process
2020-11-20 00:09:56 INFO::Creating boxplot for categorical data, case vs GO.0006796.phosphate.containing.compound.metabol
ic.process
2020-11-20 00:09:56 INFO::Creating boxplot for categorical data, case vs GO.1901265.nucleoside.phosphate.binding
2020-11-20 00:09:56 INFO::Creating boxplot for categorical data, case vs GO.0000166.nucleotide.binding
2020-11-20 00:09:56 INFO::Creating boxplot for categorical data, case vs GO.0036094.small.molecule.binding
2020-11-20 00:09:56 INFO::Creating boxplot for categorical data, case vs G0.0006082.organic.acid.metabolic.process
2020-11-20 00:09:56 INFO::Creating boxplot for categorical data, case vs GO.0044249.cellular.biosynthetic.process
2020-11-20 00:09:57 INFO::Creating boxplot for categorical data, case vs GO.0044281.small.molecule.metabolic.process
2020-11-20 00:09:57 INFO::Creating boxplot for categorical data, case vs GO.0043170.macromolecule.metabolic.process
2020-11-20 00:09:57 INFO::Creating boxplot for categorical data, case vs GO.1901576.organic.substance.biosynthetic.proces
2020-11-20 00:09:57 INFO::Creating boxplot for categorical data, case vs GO.0043436.oxoacid.metabolic.process
2020-11-20 00:09:57 INFO::Creating boxplot for categorical data, case vs GO.0019752.carboxylic.acid.metabolic.process
2020-11-20 00:09:57 INFO::Creating boxplot for categorical data, case vs G0.1901265.nucleoside.phosphate.binding
2020-11-20 00:09:57 INFO::Creating boxplot for categorical data, case vs GO.0000166.nucleotide.binding
2020-11-20 00:09:58 INFO::Creating boxplot for categorical data, case vs GO.0034660.ncRNA.metabolic.process
2020-11-20 00:09:58 INFO::Creating boxplot for categorical data, case vs GO.0044238.primary.metabolic.process
2020-11-20 00:09:58 INFO::Creating boxplot for categorical data, case vs G0.0005975.carbohydrate.metabolic.process
2020-11-20 00:09:58 INFO::Creating boxplot for categorical data, case vs GO.0019538.protein.metabolic.process
2020-11-20 00:09:58 INFO::Creating boxplot for categorical data, case vs GO.0036094.small.molecule.binding
2020-11-20 00:09:58 INFO::Creating boxplot for categorical data, case vs GO.0008652.cellular.amino.acid.biosynthetic.proc
2020-11-20 00:09:58 INFO::Creating boxplot for categorical data, case vs GO.0044877.protein.containing.complex.binding
2020-11-20 00:09:58 INFO::Creating boxplot for categorical data, case vs G0.0016835.carbon.oxygen.lyase.activity
2020-11-20 00:09:59 INFO::Creating boxplot for categorical data, case vs GO.0008652.cellular.amino.acid.biosynthetic.proc
2020-11-20 00:09:59 INFO::Creating boxplot for categorical data, case vs GO.0046483.heterocycle.metabolic.process
2020-11-20 00:09:59 INFO::Creating boxplot for categorical data, case vs GO.0016836.hydro.lyase.activity
2020-11-20 00:09:59 INFO::Creating boxplot for categorical data, case vs GO.0044283.small.molecule.biosynthetic.process
2020-11-20 00:09:59 INFO::Creating boxplot for categorical data, case vs GO.0016053.organic.acid.biosynthetic.process
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2020-11-20 00:09:59 INFO::Creating boxplot for categorical data, case vs GO.0046394.carboxylic.acid.biosynthetic.process
2020-11-20 00:09:59 INFO::Creating boxplot for categorical data, case vs GO.0006520.cellular.amino.acid.metabolic.process
2020-11-20 00:10:00 INFO::Creating boxplot for categorical data, case vs GO.0016835.carbon.oxygen.lyase.activity
2020-11-20 00:10:00 INFO::Creating boxplot for categorical data, case vs GO.0009072.aromatic.amino.acid.family.metabolic.
process
2020-11-20 00:10:00 INFO::Creating boxplot for categorical data, case vs GO.0016836.hydro.lyase.activity
2020-11-20 00:10:00 INFO::Creating boxplot for categorical data, case vs GO.0046417.chorismate.metabolic.process
2020-11-20 00:10:00 INFO::Creating boxplot for categorical data, case vs GO.0044877.protein.containing.complex.binding
2020-11-20 00:10:00 INFO::Creating boxplot for categorical data, case vs GO.0009423.chorismate.biosynthetic.process
2020-11-20 00:10:01 INFO::Creating boxplot for categorical data, case vs GO.0009073.aromatic.amino.acid.family.biosynthet
ic.process
2020-11-20 00:10:01 INFO::Creating boxplot for categorical data, case vs GO.0009423.chorismate.biosynthetic.process
2020-11-20 00:10:01 INFO::Creating boxplot for categorical data, case vs GO.0003677.DNA.binding
2020-11-20 00:10:01 INFO::Creating boxplot for categorical data, case vs G0.0006082.organic.acid.metabolic.process
2020-11-20 00:10:01 INFO::Creating boxplot for categorical data, case vs GO.0043436.oxoacid.metabolic.process
2020-11-20 00:10:01 INFO::Creating boxplot for categorical data, case vs GO.0043650.dicarboxylic.acid.biosynthetic.proces
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2020-11-20 00:10:02 INFO::Creating boxplot for categorical data, case vs GO.0003855.3.dehydroquinate.dehydratase.activity
2020-11-20 00:10:02 INFO::Creating boxplot for categorical data, case vs GO.0019752.carboxylic.acid.metabolic.process
2020-11-20 00:10:02 INFO::Creating boxplot for categorical data, case vs GO.0003855.3.dehydroquinate.dehydratase.activity
2020-11-20 00:10:02 INFO::Creating boxplot for categorical data, case vs GO.0097367.carbohydrate.derivative.binding
2020-11-20 00:10:02 INFO::Creating boxplot for categorical data, case vs GO.0097367.carbohydrate.derivative.binding
2020-11-20 00:10:02 INFO::Creating boxplot for categorical data, case vs G0.0046417.chorismate.metabolic.process
2020-11-20 00:10:02 INFO::Creating boxplot for categorical data, case vs GO.0032553.ribonucleotide.binding
2020-11-20 00:10:02 INFO::Creating boxplot for categorical data, case vs GO.0016053.organic.acid.biosynthetic.process
2020-11-20 00:10:03 INFO::Creating boxplot for categorical data, case vs GO.0046394.carboxylic.acid.biosynthetic.process
2020-11-20 00:10:03 INFO::Creating boxplot for categorical data, case vs GO.0043648.dicarboxylic.acid.metabolic.process
2020-11-20 00:10:03 INFO::Creating boxplot for categorical data, case vs GO.0032553.ribonucleotide.binding
2020-11-20 00:10:03 INFO::Creating boxplot for categorical data, case vs GO.0016070.RNA.metabolic.process
2020-11-20 00:10:03 INFO::Creating boxplot for categorical data, case vs GO.1901566.organonitrogen.compound.biosynthetic.
process
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2020-11-20 00:10:04 INFO::Creating boxplot for categorical data, case vs GO.0032555.purine.ribonucleotide.binding
2020-11-20 00:10:04 INFO::Creating boxplot for categorical data, case vs GO.0017076.purine.nucleotide.binding
2020-11-20 00:10:04 INFO::Creating boxplot for categorical data, case vs GO.0051540.metal.cluster.binding
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nding
2020-11-20 00:10:05 INFO::Creating boxplot for categorical data, case vs GO.0140098.catalytic.activity..acting.on.RNA
2020-11-20 00:10:05 INFO::Creating boxplot for categorical data, case vs GO.0035639.purine.ribonucleoside.triphosphate.bi
nding
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2020-11-20 00:10:05 INFO::Creating boxplot for categorical data, case vs G0.0051539.4.iron..4.sulfur.cluster.binding
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process
2020-11-20 00:10:05 INFO::Creating boxplot for categorical data, case vs GO.0009072.aromatic.amino.acid.family.metabolic.
process
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ic.process
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2020-11-20 00:10:06 INFO::Creating boxplot for categorical data, case vs GO.0003676.nucleic.acid.binding
2020-11-20 00:10:06 INFO::Creating boxplot for categorical data, case vs GO.0003824.catalytic.activity
2020-11-20 00:10:07 INFO::Creating boxplot for categorical data, case vs GO.0006520.cellular.amino.acid.metabolic.process
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2020-11-20 00:10:07 INFO::Creating boxplot for categorical data, case vs GO.0016874.ligase.activity
2020-11-20 00:10:07 INFO::Creating boxplot for categorical data, case vs GO.0051540.metal.cluster.binding
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osphorus.containing.groups
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ic.process
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process
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2020-11-20 00:10:09 INFO::Creating boxplot for categorical data, case vs G0.0009059.macromolecule.biosynthetic.process
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metabolic.process
2020-11-20 00:10:09 INFO::Creating boxplot for categorical data, case vs GO.0006725.cellular.aromatic.compound.metabolic.
process
2020-11-20 00:10:09 INFO::Creating boxplot for categorical data, case vs GO.1901564.organonitrogen.compound.metabolic.pro
2020-11-20 00:10:09 INFO::Creating boxplot for categorical data, case vs GO.0019637.organophosphate.metabolic.process
2020-11-20 00:10:09 INFO::Creating boxplot for categorical data, case vs GO.0016788.hydrolase.activity..acting.on.ester.b
onds
2020-11-20 00:10:10 INFO::Creating boxplot for categorical data, case vs GO.0016817.hydrolase.activity..acting.on.acid.an
hydrides
2020-11-20 00:10:10 INFO::Creating boxplot for categorical data, case vs GO.0016818.hydrolase.activity..acting.on.acid.an
hydrides..in.phosphorus.containing.anhydrides
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2020-11-20 00:10:10 INFO::Creating boxplot for categorical data, case vs GO.0006725.cellular.aromatic.compound.metabolic.
process
2020-11-20 00:10:10 INFO::Creating boxplot for categorical data, case vs G0.0006793.phosphorus.metabolic.process
2020-11-20 00:10:10 INFO::Creating boxplot for categorical data, case vs GO.0006796.phosphate.containing.compound.metabol
ic.process
2020-11-20 00:10:10 INFO::Creating boxplot for categorical data, case vs G0.0016462.pyrophosphatase.activity
2020-11-20 00:10:10 INFO::Creating boxplot for categorical data, case vs GO.0016787.hydrolase.activity
2020-11-20 00:10:11 INFO::Creating boxplot for categorical data, case vs GO.0008150.biological process
2020-11-20 00:10:11 INFO::Creating boxplot for categorical data, case vs GO.0008233.peptidase.activity
2020-11-20 00:10:11 INFO::Creating boxplot for categorical data, case vs GO.0006810.transport
2020-11-20 00:10:11 INFO::Creating boxplot for categorical data, case vs GO.0006753.nucleoside.phosphate.metabolic.proces
2020-11-20 00:10:11 INFO::Creating boxplot for categorical data, case vs G0.0009117.nucleotide.metabolic.process
2020-11-20 00:10:11 INFO::Creating boxplot for categorical data, case vs GO.0003674.molecular function
2020-11-20 00:10:11 INFO::Creating boxplot for categorical data, case vs GO.0006810.transport
2020-11-20 00:10:12 INFO::Creating boxplot for categorical data, case vs GO.0016787.hydrolase.activity
2020-11-20 00:10:12 INFO::Creating boxplot for categorical data, case vs GO.0051234.establishment.of.localization
2020-11-20 00:10:12 INFO::Creating boxplot for categorical data, case vs GO.0017111.nucleoside.triphosphatase.activity
2020-11-20 00:10:12 INFO::Creating boxplot for categorical data, case vs GO.0051179.localization
2020-11-20 00:10:12 INFO::Creating boxplot for categorical data, case vs GO.0043167.ion.binding
2020-11-20 00:10:12 INFO::Creating boxplot for categorical data, case vs GO.0140096.catalytic.activity..acting.on.a.prote
2020-11-20 00:10:12 INFO::Creating boxplot for categorical data, case vs GO.0016779.nucleotidyltransferase.activity
2020-11-20 00:10:12 INFO::Creating boxplot for categorical data, case vs GO.0072521.purine.containing.compound.metabolic.
2020-11-20 00:10:13 INFO::Creating boxplot for categorical data, case vs GO.0016829.lyase.activity
```

\$results A data.frame: 232 × 10

	coef	value	metadata	feature
	<dbl></dbl>	<chr></chr>	<chr></chr>	<chr></chr>
0.00	0.003981729	Control_Healthy	case	GO.0034660.ncRNA.metabolic.process
0.00	0.009075342	Control_Sick	case	GO.0016740.transferase.activity
0.00	0.002885018	Control_Healthy	case	GO.0140098.catalytic.activityacting.on.RNA
0.00	0.005589451	Control_Healthy	case	GO.0043170.macromolecule.metabolic.process
0.00	0.004123315	Control_Healthy	case	GO.0016070.RNA.metabolic.process
0.00	0.001399883	Control_Healthy	case	GO.0019538.protein.metabolic.process

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feature	metadata	value	coef	
<chr></chr>	<chr></chr>	<chr></chr>	<dbl></dbl>	
GO.0016740.transferase.activity	case	Control_Healthy	0.007359575	0.00
GO.0043168.anion.binding	case	Control_Healthy	0.001858915	0.00
GO.1901362.organic.cyclic.compound.biosynthetic.process	case	Control_Healthy	-0.002910851	0.00
GO.0044260.cellular.macromolecule.metabolic.process	case	Control_Healthy	0.002850432	0.00
GO.0003676.nucleic.acid.binding	case	Control_Sick	-0.002974457	0.00
GO.0065007.biological.regulation	case	Control_Healthy	0.002747947	0.00
GO.0003677.DNA.binding	case	Control_Sick	-0.002225029	0.00
GO.0016772.transferase.activitytransferring.phosphorus.containing.groups	case	Control_Sick	0.005475526	0.00
GO.0009987.cellular.process	case	Control_Healthy	0.006062118	0.00
GO.0050794.regulation.of.cellular.process	case	Control_Healthy	0.002335097	0.00
GO.0090304.nucleic.acid.metabolic.process	case	Control_Healthy	0.003677832	0.00
GO.0050789.regulation.of.biological.process	case	Control_Healthy	0.002322823	0.00
GO.0044260.cellular.macromolecule.metabolic.process	case	Control_Sick	0.002371719	0.00
GO.0016829.lyase.activity	case	Control_Healthy	-0.004643479	0.00
GO.0016779.nucleotidyltransferase.activity	case	Control_Sick	0.003828213	0.00

feature	metadata	value	coef	
<chr></chr>	<chr></chr>	<chr></chr>	<dbl></dbl>	
GO.0034645.cellular.macromolecule.biosynthetic.process	case	Control_Sick	0.001793419	0.00
GO.0044281.small.molecule.metabolic.process	case	Control_Healthy	-0.004324793	0.00
GO.0044283.small.molecule.biosynthetic.process	case	Control_Healthy	-0.004540546	0.00
GO.0009987.cellular.process	case	Control_Sick	0.004905174	0.00
GO.0009059.macromolecule.biosynthetic.process	case	Control_Sick	0.001745069	0.00
GO.0019438.aromatic.compound.biosynthetic.process	case	Control_Healthy	-0.002051294	0.00
GO.0044262.cellular.carbohydrate.metabolic.process	case	Control_Sick	0.002421115	0.00
GO.0019438.aromatic.compound.biosynthetic.process	case	Control_Sick	-0.001938171	0.00
GO.1901566.organonitrogen.compound.biosynthetic.process	case	Control_Healthy	-0.002981672	0.00
:	:	:	:	
GO.0001882.nucleoside.binding	case	Control_Healthy	5.863199e-05	1.07
GO.0032549.ribonucleoside.binding	case	Control_Healthy	5.872475e-05	1.07
GO.0019001.guanyl.nucleotide.binding	case	Control_Sick	5.523391e-05	1.02
GO.0032561.guanyl.ribonucleotide.binding	case	Control_Sick	5.493212e-05	1.02
GO.0043169.cation.binding	case	Control_Sick	4.762072e-04	9.03
GO.0071704.organic.substance.metabolic.process	case	Control_Healthy	5.885809e-04	1.13
GO.0005215.transporter.activity	case	Control_Sick	-2.138713e- 04	4.30
GO.0001883.purine.nucleoside.binding	case	Control_Sick	4.841929e-05	1.01

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	coef	value	metadata	feature
	<dbl></dbl>	<chr></chr>	<chr></chr>	<chr></chr>
1.01	-6.899274e- 06	Control_Healthy	case	GO.0043022.ribosome.binding
6.99	-1.558900e- 05	Control_Sick	case	GO.0044238.primary.metabolic.process

\$residuals

	1	
GO.0008150.biological_process	1.050308e- 03	0.002671
GO.0008152.metabolic.process	1.967926e- 03	0.002084
GO.0051179.localization	-1.096149e- 03	-0.000227
GO.0065007.biological.regulation	-1.735470e- 04	-0.000647
GO.0009987.cellular.process	4.027215e- 03	0.003487
GO.0044237.cellular.metabolic.process	3.258478e- 03	0.002986
GO.0050789.regulation.of.biological.process	-4.025308e- 04	-0.000741
GO.0044238.primary.metabolic.process	-8.640054e- 05	-0.001704
GO.0071704.organic.substance.metabolic.process	2.111104e- 03	0.000530
GO.0006807.nitrogen.compound.metabolic.process	5.247134e- 04	-0.002390
GO.0051234.establishment.of.localization	-1.095399e- 03	-0.000227
GO.0009058.biosynthetic.process	2.696740e- 03	0.003096

1	

GO.0044281.small.molecule.metabolic.process	-4.001232e- 04	-0.001376
GO.0044283.small.molecule.biosynthetic.process	3.578024e- 04	-0.000598
GO.1901360.organic.cyclic.compound.metabolic.process	3.092047e- 03	0.000303
GO.0034641.cellular.nitrogen.compound.metabolic.process	3.431093e- 03	0.001800
GO.0046483.heterocycle.metabolic.process	3.578329e- 03	0.001777
GO.0006082.organic.acid.metabolic.process	-3.351721e- 03	-0.004956
GO.0043170.macromolecule.metabolic.process	2.782860e- 03	0.000701
GO.0006725.cellular.aromatic.compound.metabolic.process	-7.259887e- 04	-0.003856
GO.0006810.transport	-1.130341e- 03	-0.000262
GO.0071941.nitrogen.cycle.metabolic.process	-1.256314e- 03	-0.001511
GO.0044249.cellular.biosynthetic.process	9.054021e- 04	0.000920
GO.0050794.regulation.of.cellular.process	-3.717222e- 04	-0.000776
GO.0005975.carbohydrate.metabolic.process	1.194613e- 03	0.002485
GO.1901564.organonitrogen.compound.metabolic.process	9.787501e- 04	0.000407
GO.0006793.phosphorus.metabolic.process	1.465548e- 04	0.001891
GO.1901576.organic.substance.biosynthetic.process	9.139901e- 04	0.000952

	1	
GO.1901362.organic.cyclic.compound.biosynthetic.process	1.503030e- 03	0.001804
GO.1901566.organonitrogen.compound.biosynthetic.process	1.100834e- 03	0.000877
E .	:	
GO.0001882.nucleoside.binding	-3.003590e- 07	1.04170€
GO.0016788.hydrolase.activityacting.on.ester.bonds	5.390783e- 04	-2.862558
GO.0043021.ribonucleoprotein.complex.binding	5.093344e- 08	4.446448
GO.1901265.nucleoside.phosphate.binding	-2.767435e- 04	-2.39077(
GO.0003676.nucleic.acid.binding	-1.417264e- 03	-1.839515
GO.0051536.iron.sulfur.cluster.binding	-2.660612e- 03	-3.13233(
GO.0043169.cation.binding	2.233725e- 03	2.501048
GO.0004518.nuclease.activity	4.558782e- 04	-2.475269
GO.0016779.nucleotidyltransferase.activity	2.006040e- 04	2.479733
GO.0001883.purine.nucleoside.binding	-3.579259e- 07	-1.449427
GO.0046872.metal.ion.binding	2.219931e- 03	2.434188
GO.0003677.DNA.binding	-5.606521e- 04	-1.005526

GO.0016836.hydro.lyase.activity

-4.785183e-04

-8.838041

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	1	
GO.0043022.ribosome.binding	2.553842e- 09	4.358936
GO.0016818. hydrolase. activity acting. on. acid. anhydrides in. phosphorus. containing. anhydrides. on.	-1.012493e- 04	-6.870434
GO.0035639.purine.ribonucleoside.triphosphate.binding	-8.854684e- 05	-6.67497(
GO.0051539.4.iron4.sulfur.cluster.binding	-1.307937e- 03	-1.565684
GO.0000166.nucleotide.binding	-2.767435e- 04	-2.39077(
GO.0032549.ribonucleoside.binding	-2.981624e- 07	1.063892
GO.0016462.pyrophosphatase.activity	-1.055595e- 04	-6.686687
GO.0032550.purine.ribonucleoside.binding	-3.557352e- 07	-1.42927(
GO.0003855.3.dehydroquinate.dehydratase.activity	-5.109609e- 04	-9.645095
GO.0032553.ribonucleotide.binding	-7.401135e- 05	-3.101592
GO.0017076.purine.nucleotide.binding	-8.525448e- 05	-5.481546
GO.0032555.purine.ribonucleotide.binding	-8.417166e- 05	-5.643708
GO.0019001.guanyl.nucleotide.binding	-3.225791e- 07	-6.092192
GO.0017111.nucleoside.triphosphatase.activity	-1.094893e- 04	-7.335700
GO.0032561.guanyl.ribonucleotide.binding	-3.297811e- 07	-7.310278
GO.0003924.GTPase.activity	-3.044794e- 07	-2.255327

1

```
GO.0005525.GTP.binding -3.547081e-
```

```
In [ ]:
```

OK OK OK OK NEXT I HAVE TO DO THIS ON THE COVID19 CASES ONLY (OR MAYBE ALL THE CASES AND JUST DELINEATE COVID19 BY OUTCOME) AND DO IT BY OUTCOME

DMM modeling using the MaAslin2 derived terms

Ok, lets import the MaAsLin2 derived significant terms

```
In [27]: sig<-read.table("Significant_Go_terms_for_Beth_Maaslin2.txt",header = T,sep = "\t")
head(sig)</pre>
```

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A data.frame: 6×12

	GO_Tag	name	metadata	value. as. compared. to. COVID 19.	coef	stderr	N	N.not.0	pval	qval	
	<chr></chr>	<chr></chr>	<chr></chr>	<chr></chr>	<dbl></dbl>	<dbl></dbl>	<int></int>	<int></int>	<dbl></dbl>	<dbl></dbl>	
1	GO:0034660	ncRNA metabolic process	case	Control_Healthy	0.003981729	0.000636300	141	133	6.14e- 09	9.21e- 07	GO.
2	GO:0016740	transferase activity	case	Control_Sick	0.009075342	0.001469230	141	135	1.00e- 08	9.21e- 07	
3	GO:0140098	catalytic activity acting on RNA	case	Control_Healthy	0.002885018	0.000469004	141	134	1.19e- 08	9.21e- 07	GO.01400
4	GO:0043170	macromolecule metabolic process	case	Control_Healthy	0.005589451	0.000911267	141	136	5.98e- 08	3.47e- 06	GO.0043170
5	GO:0016070	RNA metabolic process	case	Control_Healthy	0.004123315	0.000725339	141	135	9.00e- 08	4.17e- 06	G
6	GO:0019538	protein metabolic process	case	Control_Healthy	0.001399883	0.000264455	141	134	6.08e- 07	2.35e- 05	GO.(
•											+

DMM Preprocessing / filtering

Ok lets filter out the GO_tag mataches from our phyloseq object

```
Terms<-sig$GO_Tag
In [28]:
In [29]:
          bac_pseq_no_neg<-subset_samples(bac_pseq, sample_type!="neg_control")</pre>
          bac pseq no neg<-subset samples(bac pseq no neg, sample type!="Unknown")
          bac pseq no neg# [ 13846 taxa and 141 samples ]:
         phyloseq-class experiment-level object
         otu table() OTU Table:
                                           [ 13846 taxa and 141 samples ]
         sample data() Sample Data:
                                           [ 141 samples by 71 sample variables ]
                                           [ 13846 taxa by 3 taxonomic ranks ]
         tax table()
                       Taxonomy Table:
          bac_pseq_prune<-prune_taxa(x = bac_pseq_no_neg,taxa = Terms)</pre>
In [30]:
          bac pseq prune #[ 92 taxa and 141 samples ]
```

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```
phyloseq-class experiment-level object
                      OTU Table:
         otu table()
                                            [ 92 taxa and 141 samples ]
                                            [ 141 samples by 71 sample variables ]
         sample data() Sample Data:
         tax table() Taxonomy Table:
                                            [ 92 taxa by 3 taxonomic ranks ]
         ok lets rename our GO_terms again
          tax<-data.frame(tax table(bac pseq prune))</pre>
In [31]:
          names<-paste(rownames(tax),tax$name,sep="-")</pre>
          length(names)
          taxa names(bac pseq prune)<-names
         92
         filter out the depth 0 mol fxn and bio proc, empty GO Terms, and empty samples
In [32]:
          bac pseq prune
```

```
In [32]: bac_pseq_prune
    filtme<-c("GO:0003674-molecular_function")
    bac_pseq_prune <- prune_taxa(taxa=taxa_names(bac_pseq_prune)!=filtme, bac_pseq_prune)
    bac_pseq_prune
    filtme<-c("GO:0008150-biological_process")
    bac_pseq_prune <- prune_taxa(taxa=taxa_names(bac_pseq_prune)!=filtme, bac_pseq_prune)
    bac_pseq_prune
    bac_pseq_prune <- prune_samples(sample_sums(bac_pseq_prune)) > 1, bac_pseq_prune)
    #bac_pseq_prune#[ 92 taxa and 141 samples ]
    bac_pseq_prune #[ 92 taxa and 141 samples ]
```

```
phyloseq-class experiment-level object
otu table() OTU Table:
                                [ 92 taxa and 141 samples ]
                                 [ 141 samples by 71 sample variables ]
sample data() Sample Data:
                                 [ 92 taxa by 3 taxonomic ranks ]
tax table() Taxonomy Table:
phyloseq-class experiment-level object
             OTU Table:
otu table()
                                 [ 91 taxa and 141 samples ]
                                  141 samples by 71 sample variables ]
sample data() Sample Data:
tax table() Taxonomy Table:
                                [ 91 taxa by 3 taxonomic ranks ]
phyloseq-class experiment-level object
             OTU Table:
otu table()
                                 [ 90 taxa and 141 samples ]
sample data() Sample Data:
                                 [ 141 samples by 71 sample variables ]
tax table() Taxonomy Table:
                                 [ 90 taxa by 3 taxonomic ranks ]
phyloseq-class experiment-level object
otu table()
             OTU Table:
                                  90 taxa and 141 samples ]
sample_data() Sample Data:
                                 [ 141 samples by 71 sample variables ]
tax table()
             Taxonomy Table:
                                [ 90 taxa by 3 taxonomic ranks ]
```

DMM modeling time

convert counts to a matrix

10.16.5.38:8888/lab? 143/151

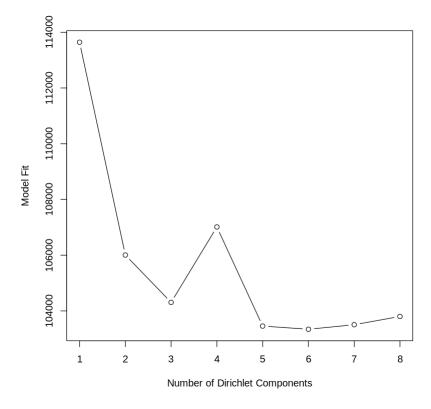
```
In [33]: dat <- abundances(bac_pseq_prune)
    count <- as.matrix(t(dat))</pre>
```

Fit the dmm model

```
In [34]: fit <- mclapply(1:8, dmn, count = count, verbose=TRUE)</pre>
```

Check the model fit with different number of mixture componenets using standard information criteria

```
In [35]: lplc <- sapply(fit, laplace) # AIC / BIC / Laplace
aic <- sapply(fit, AIC) # AIC / BIC / Laplace
bic <- sapply(fit, BIC) # AIC / BIC / Laplace
plot(lplc, type="b", xlab="Number of Dirichlet Components", ylab="Model Fit")</pre>
```



```
In [36]: #identify the number of clusters that best fits the model
In [37]: best <- fit[[which.min(lplc)]]</pre>
```

10.16.5.38:8888/lab? 144/151

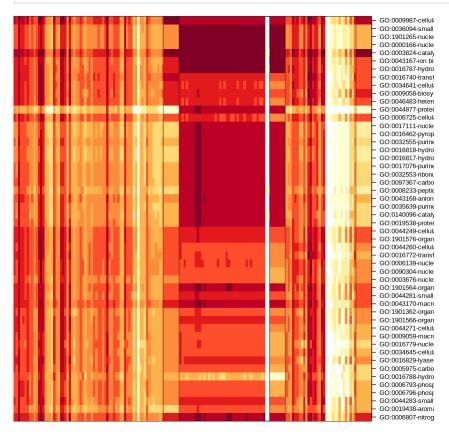
```
best <-fit[[3]]
best

class: DMN
k: 3
samples x taxa: 141 x 90
Laplace: 104305.2 BIC: 104203.3 AIC: 103802.2

In [38]: #save.image(file = "go_terms_dmm.rdata")</pre>
```

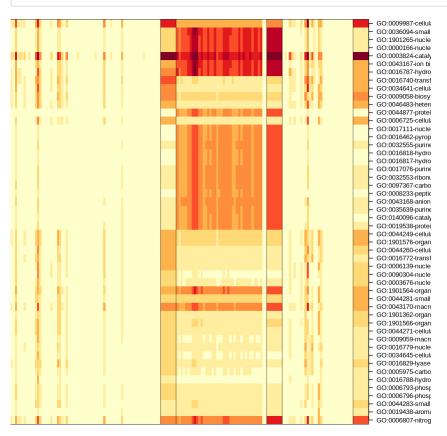
make a heatmap visualization of the cluster

log 2 Heatmap



square root version

10.16.5.38:8888/lab? 145/151



print out the theta values

In [41]: mixturewt(best)

A data.frame: 3×2

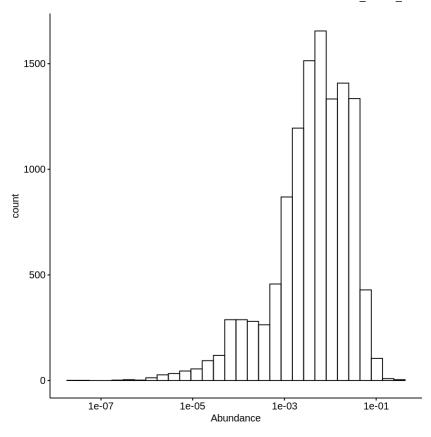
pi	theta
bl>	<dbl></dbl>
277	708.70467
241	10503.53447
482	79.21304

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save the datasheet that show which GO terms contributed to each dmm group

```
write.table(fitted(best), "GO_TERMS_DMM_contributions.tsv", sep="\t")
In [42]:
         save a datasheet that identifies which sample belongs to which dmm group
In [43]:
          ass <- apply(mixture(best), 1, which.max)</pre>
          write.table(ass,"GO TERMS DMM groups.tsv",sep="")
In [44]:
          #add the dmm group to the metadata
           sample data(bac pseq prune)$dmn<-ass</pre>
           bac pseq prune comp<-microbiome::transform(bac pseq prune, "compositional")</pre>
           #melt the phyloseq object into tidy form
           tmp<-psmelt(bac pseq prune comp)</pre>
           tmp<-as tibble(tmp)</pre>
          gghistogram(tmp,x = "Abundance",y = "..count..")+scale x log10() #move each dmm group into a colum of its own
In [45]:
          Warning message:
          "Using `bins = 30` by default. Pick better value with the argument `bins`."
          Warning message:
          "Transformation introduced infinite values in continuous x-axis"
          Warning message:
          "Removed 861 rows containing non-finite values (stat_bin)."
```

10.16.5.38:8888/lab? 147/151



```
In [46]: #tmp$log2Abundance<-log2(tmp$Abundance)</pre>
```

In [47]: #subset the dataset to only include the case, Go_term, count, and dmm group.
#obtain the avergage count for each Go term
#order the go terms from hight to lowest count

I added these filtering commands to pull out the counts with less than 1% relabund or greater tahn 22% (ie:molecular function)

```
In [48]: d2<-tmp %>%
    select(case,OTU,Abundance, dmn)%>%
    group_by(OTU,case, dmn) %>%
    summarise(avg = mean(Abundance)) %>%
    arrange(desc(avg))
```

`summarise()` regrouping output by 'OTU', 'case' (override with `.groups` argument)

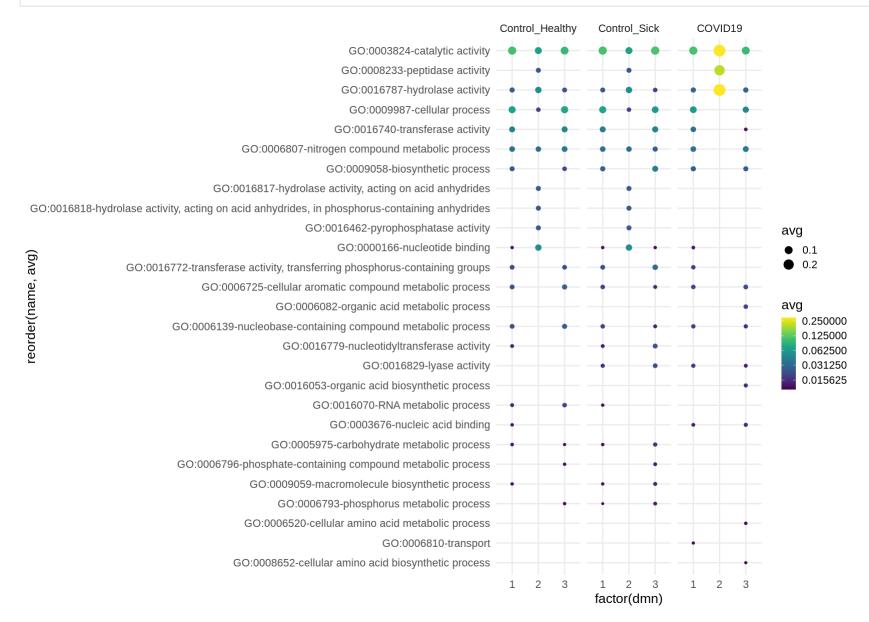
```
In [49]: #d2$avg<-sqrt(d2$avg)
```

10.16.5.38:8888/lab?

```
In [50]:
          d3<-tidyr::spread(d2,dmn, avg)
          #get the total count of the go terms and oder from greates to lowest
In [51]:
          d3<-tidyr::spread(d2,dmn,avg)</pre>
In [52]:
           d3$tot<-rowSums(d3[3:5], na.rm = T)
           d3<-d3%>%arrange(desc(tot))
           d3$tot<-NULL
           head(d3)
                                              A grouped_df: 6 \times 5
                                             OTU
                                                                                    2
                                                                                                3
                                                           case
                                                                         1
                                           <chr>
                                                          <chr>
                                                                      <dbl>
                                                                                <dbl>
                                                                                            <dbl>
                         GO:0003824-catalytic activity
                                                        COVID19 0.109352879 0.29285714 0.097175968
                        GO:0016787-hydrolase activity
                                                        COVID19 0.028312042 0.29285714 0.028805605
                          GO:0003824-catalytic activity
                                                     GO:0003824-catalytic activity Control_Healthy 0.107499082 0.06891539 0.096723461
          GO:0140096-catalytic activity, acting on a protein
                                                        COVID19 0.004725500 0.20714286 0.005114505
                        GO:0008233-peptidase activity
                                                        COVID19 0.003253628 0.20714286 0.004649460
          d3<-d3%>%gather(data = d3,avg,3:5)
In [53]:
           colnames(d3)<-c("name", "case", "dmn", "avg")</pre>
         make the balloon plot
In [54]:
          d4<-d3%>%filter(avg>0.01)%>%arrange(name, case, dmn)
           d4<-d4[1:108,]
          my pal<-viridis(n = 256, alpha = 1, begin = 0, end = 1, direction = 1)
In [93]:
In [116...
          options(repr.plot.width=14, repr.plot.height=10)
           a<-ggplot(data = d4,mapping = aes(x = factor(dmn),y =reorder(name,avg),size=avg,color=avg))+
           geom point()+
           #theme(text=element text(size=20))+
           scale colour gradientn(colours = my pal,trans="log2")+
           facet grid(facets = ~ case)+
```

10.16.5.38:8888/lab? 149/151

```
theme_minimal(base_size = 16)
a
```



10.16.5.38:8888/lab? 150/151

In []:

10.16.5.38:8888/lab? 151/151