

# Week 4 - Data Science II

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Today: Classification models

```
# Applied Data Science II - Week 3
```

```
# # -----
```

```
# Today we are going to talk about CLASSIFICATION MODELS!
```

```
#
```

```
#
```

```
# # -----
```

```
#
```

```
# Load your libraries!
```

```
#
```

```
# # -----
```

```
library(ISLR2)
```

```
library(tidyverse)
```

```
## -- Attaching packages ----- tidyverse 1.3.1 --
```

```
## v ggplot2 3.3.5      v purrr  0.3.4
```

```
## v tibble  3.1.6      v dplyr  1.0.7
```

```
## v tidyr   1.1.4      v stringr 1.4.0
```

```
## v readr   2.1.0      v forcats 0.5.1
```

```
## -- Conflicts ----- tidyverse_conflicts() --
```

```
## x dplyr::filter() masks stats::filter()
```

```
## x dplyr::lag()    masks stats::lag()
```

```
library(caret)
```

```
## Loading required package: lattice
```

```
##
```

```
## Attaching package: 'caret'
```

```
## The following object is masked from 'package:purrr':
##
## lift
```

```
library(palmerpenguins)
library(class)
library(nnet)
```

```
# do these not work? Then you'll have to install them!
```

```
# Uncomment the line below and run this command:
# install.packages(c("palmerpenguins", "caret", "class", "nnet"))
```

```
# # -----
#
# Logistic Regression
#
# # -----
```

```
# The textbook is too dry. Let's have some fun with our own data!
# Let's try and build a predictive model of PENGUINS.
```

```
# These data were collected and made available by Dr. Kristen Gorman and the Palmer Station,
# Antarctica LTER, a member of the Long Term Ecological Research Network.
```

```
# For more information, see here: https://github.com/allisonhorst/palmerpenguins
```

```
attach(penguins)
head(penguins)
```

```
## # A tibble: 6 x 8
##   species island bill_length_mm bill_depth_mm flipper_length_~ body_mass_g sex
##   <fct>   <fct>         <dbl>         <dbl>         <int>     <int> <fct>
## 1 Adelie Torge~         39.1           18.7           181       3750 male
## 2 Adelie Torge~         39.5           17.4           186       3800 fema~
## 3 Adelie Torge~         40.3           18            195       3250 fema~
## 4 Adelie Torge~         NA            NA            NA         NA <NA>
## 5 Adelie Torge~         36.7           19.3           193       3450 fema~
## 6 Adelie Torge~         39.3           20.6           190       3650 male
## # ... with 1 more variable: year <int>
```

```
# Let's check out some summaries!
```

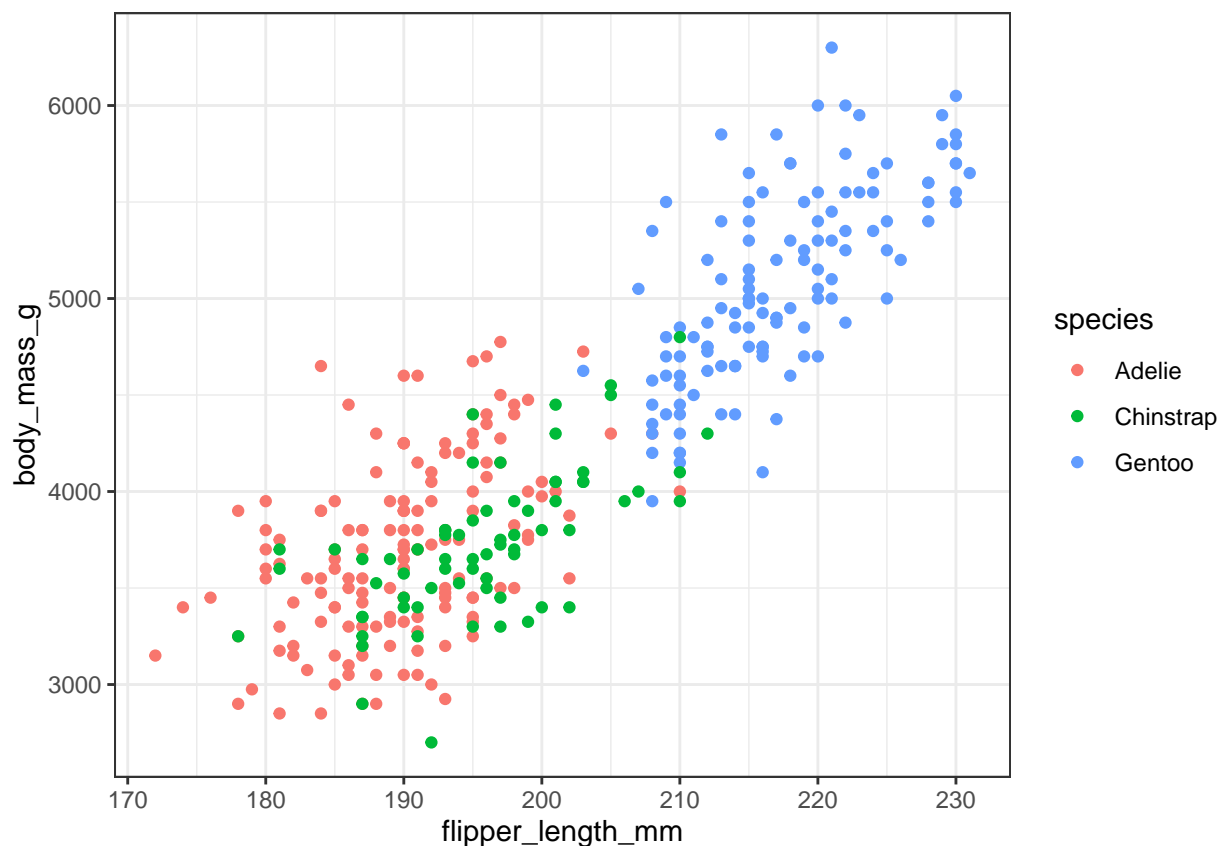
```
# We've got a good number of different measurements for each class!
```

```
penguins %>%
  count(species)
```

```
## # A tibble: 3 x 2
##   species      n
##   <fct>    <int>
## 1 Adelie    152
## 2 Chinstrap  68
## 3 Gentoo    124
```

```
# Gentoo seems easy enough to classify, but Chinstrap and Adelie are nice and mixed up.
penguins %>%
  ggplot(aes(x = flipper_length_mm, y = body_mass_g, fill = species, color = species)) +
  geom_point() +
  theme_bw()
```

```
## Warning: Removed 2 rows containing missing values (geom_point).
```



```
# Okay. Here is our scenario.
# An awesome COA student has spilled their coffee onto their data notebook while taking the
# Antarctica monster course. All they have left now are the bill length measurements.
# They think they can tell the scribbles of the species between "A"
# and something that looks like a "c" or a "g" - so we're going to build a model that predicts
# penguin was actually an Adelie penguin or not!
```

```
penguins_cleaned <- penguins %>%
  drop_na() %>%
  select(species, bill_length_mm) %>%
  mutate(adelie = as.factor(ifelse(species == 'Adelie',1,0))) %>%
  select(-species)

head(penguins_cleaned)
```

```
## # A tibble: 6 x 2
##   bill_length_mm adelie
##           <dbl> <fct>
## 1           39.1 1
## 2           39.5 1
## 3           40.3 1
## 4           36.7 1
## 5           39.3 1
## 6           38.9 1
```

*# Let's build a logistic model first, then we'll do some training/testing splits.*

*# GLM stands for general linear model*

```
penguins_glm <- glm(adelie ~ ., family = binomial(link="logit"), data = penguins_cleaned)
# family= binomial(link="logit") means: make this a logistic model.
```

*# Okay, let's check the summary!*

```
summary(penguins_glm)
```

```
##
## Call:
## glm(formula = adelie ~ ., family = binomial(link = "logit"),
##      data = penguins_cleaned)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.19736  -0.10603  -0.00907   0.09103   2.71320
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    50.2432     6.9176   7.263 3.78e-13 ***
## bill_length_mm  -1.1717     0.1615  -7.255 4.02e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 456.575  on 332  degrees of freedom
```

```
## Residual deviance: 90.248 on 331 degrees of freedom
## AIC: 94.248
##
## Number of Fisher Scoring iterations: 8
```

```
# So what's this stuff...
```

```
# The coefficients are the same as you remember!
```

```
# Next we see the deviance residuals, which are a measure of model fit.
```

```
# This part of output shows the distribution of the deviance residuals for individual cases us
```

```
# You don't get an R2 in this model.
```

```
# Let's get an idea of how this model behaved! First, let's get some predicted values
```

```
penguins_probs <- predict(penguins_glm, type = "response")
```

```
# if you're getting stuff in scientific notation - try running this line of code!
options(scipen = 999)
```

```
penguins_probs
```

```
##           1           2           3           4
## 0.988220717036022 0.981309671265097 0.953625357684732 0.999284386971268
##           5           6           7           8
## 0.985156271336827 0.990658515508625 0.986775785819395 0.889550147702503
##           9          10          11          12
## 0.993408860869606 0.999938857064008 0.999363459394796 0.992595576080760
##          13          14          15          16
## 0.609632487119766 0.999951629691625 0.025204653246165 0.997408128705227
##          17          18          19          20
## 0.997694041871878 0.999719601669650 0.995864891484419 0.991682779757158
##          21          22          23          24
## 0.999861158923333 0.935354473029238 0.942088166986341 0.997086868994476
##          25          26          27          28
## 0.942088166986341 0.981309671265097 0.998715118098660 0.981309671265097
##          29          30          31          32
## 0.910560281146165 0.999496370816414 0.986775785819395 0.991682779757158
##          33          34          35          36
## 0.689392149364658 0.997948480405119 0.973644530337640 0.999433799577241
##          37          38          39          40
## 0.919654776412670 0.999684756039061 0.193260792644032 0.998983267230167
##          41          42          43          44
## 0.979034966808781 0.889550147702503 0.999684756039061 0.663762936849391
##          45          46          47          48
## 0.979034966808781 0.962954491122013 0.999902304092005 0.737229851399292
##          49          50          51          52
```

##	0.999945617053413	0.850005331209998	0.989509447648365	0.935354473029238
##	53	54	55	56
##	0.999433799577241	0.997948480405119	0.999778166115783	0.864339869687895
##	57	58	59	60
##	0.997948480405119	0.889550147702503	0.999496370816414	0.817619502490325
##	61	62	63	64
##	0.999824500844814	0.889550147702503	0.999719601669650	0.780050549449687
##	65	66	67	68
##	0.999983149447928	0.976490052210829	0.979034966808781	0.031649922544640
##	69	70	71	72
##	0.999824500844814	0.523546629365398	0.910560281146165	0.998715118098660
##	73	74	75	76
##	0.999601541034387	0.713909815482670	0.999938857064008	0.494271691837775
##	77	78	79	80
##	0.999284386971268	0.999890160742255	0.998555623746504	0.864339869687895
##	81	82	83	84
##	0.999552030359750	0.999095582086255	0.995353240303491	0.990658515508625
##	85	86	87	88
##	0.999778166115783	0.889550147702503	0.999969728025012	0.979034966808781
##	89	90	91	92
##	0.999601541034387	0.919654776412670	0.996320413408978	0.953625357684732
##	93	94	95	96
##	0.999989454409287	0.407472061440141	0.999902304092005	0.900547678722457
##	97	98	99	100
##	0.997694041871878	0.997408128705227	0.997086868994476	0.976490052210829
##	101	102	103	104
##	0.993408860869606	0.995864891484419	0.996320413408978	0.407472061440141
##	105	106	107	108
##	0.996320413408978	0.039676275595187	0.976490052210829	0.689392149364658
##	109	110	111	112
##	0.979034966808781	0.552660657555397	0.993408860869606	0.998555623746504
##	113	114	115	116
##	0.999778166115783	0.889550147702503	0.999601541034387	0.997694041871878
##	117	118	119	120
##	0.958540253015996	0.850005331209998	0.999876508191821	0.935354473029238
##	121	122	123	124
##	0.991682779757158	0.834446247247095	0.989509447648365	0.193260792644032
##	125	126	127	128
##	0.994133344312952	0.436038564442355	0.999195499910916	0.998174895646024
##	129	130	131	132
##	0.996320413408978	0.889550147702503	0.999802688660152	0.958540253015996
##	133	134	135	136
##	0.998983267230167	0.976490052210829	0.958540253015996	0.935354473029238
##	137	138	139	140
##	0.999996732548339	0.927897742763630	0.998555623746504	0.989509447648365
##	141	142	143	144
##	0.986775785819395	0.999363459394796	0.999684756039061	0.997408128705227
##	145	146	147	148

##	0.999684756039061	0.834446247247095	0.022480512789384	0.000238234249582
##	149	150	151	152
##	0.001091836498613	0.000238234249582	0.003950611381065	0.014188249578453
##	153	154	155	156
##	0.049633764834004	0.011257579328480	0.379517632418790	0.010025347461247
##	157	158	159	160
##	0.910560281146165	0.000768490840574	0.044389538108148	0.001551019985110
##	161	162	163	164
##	0.031649922544640	0.000540851641837	0.737229851399292	0.000608044611701
##	165	166	167	168
##	0.020044745440700	0.001091836498613	0.000188474600895	0.069095656504892
##	169	170	171	172
##	0.014188249578453	0.017868069780125	0.494271691837775	0.022480512789384
##	173	174	175	176
##	0.003127878735650	0.001959803502387	0.000238234249582	0.005605336543366
##	177	178	179	180
##	0.523546629365398	0.069095656504892	0.000000003104593	0.000683579623799
##	181	182	183	184
##	0.001551019985110	0.581418011419911	0.144244942927215	0.212187559235968
##	185	186	187	188
##	0.001091836498613	0.552660657555397	0.000380617106200	0.055461592170561
##	189	190	191	192
##	0.000380617106200	0.000132622625720	0.300880701827437	0.044389538108148
##	193	194	195	196
##	0.000132622625720	0.085776993009259	0.061929112851855	0.012639333147495
##	197	198	199	200
##	0.001379765836737	0.069095656504892	0.000211899117165	0.014188249578453
##	201	202	203	204
##	0.077023430468890	0.253989168336927	0.044389538108148	0.407472061440141
##	205	206	207	208
##	0.000149106629150	0.055461592170561	0.020044745440700	0.035444902856469
##	209	210	211	212
##	0.000001545211482	0.031649922544640	0.000301127110317	0.000427911782653
##	213	214	215	216
##	0.326086940330321	0.000104919611649	0.003515341845205	0.015923920269599
##	217	218	219	220
##	0.001959803502387	0.014188249578453	0.015923920269599	0.001227397280175
##	221	222	223	224
##	0.004439535866393	0.000065664064863	0.061929112851855	0.061929112851855
##	225	226	227	228
##	0.000683579623799	0.000012733268303	0.004988666196606	0.000238234249582
##	229	230	231	232
##	0.085776993009259	0.000093320105773	0.352340603665757	0.000051947032229
##	233	234	235	236
##	0.004439535866393	0.000020346164172	0.004439535866393	0.000018096601846
##	237	238	239	240
##	0.044389538108148	0.000427911782653	0.130375607414044	0.000093320105773
##	241	242	243	244

##	0.000481080367295	0.008926775471448	0.001551019985110	0.000065664064863
##	245	246	247	248
##	0.001379765836737	0.000000237030729	0.006297753666908	0.000683579623799
##	249	250	251	252
##	0.010025347461247	0.799493453752551	0.000004435729790	0.379517632418790
##	253	254	255	256
##	0.002202892109700	0.000132622625720	0.000301127110317	0.326086940330321
##	257	258	259	260
##	0.000041095330150	0.020044745440700	0.000000605196508	0.000971233266472
##	261	262	263	264
##	0.006297753666908	0.010025347461247	0.000149106629150	0.061929112851855
##	265	266	267	268
##	0.000267841473977	0.014188249578453	0.000238234249582	0.000051947032229
##	269	270	271	272
##	0.049633764834004	0.000010073214110	0.061929112851855	0.022480512789384
##	273	274	275	276
##	0.000051947032229	0.025204653246165	0.000051947032229	0.012639333147495
##	277	278	279	280
##	0.000032510468049	0.007947617958034	0.000022875359931	0.028249359489604
##	281	282	283	284
##	0.000132622625720	0.000167639127777	0.000000020238972	0.015923920269599
##	285	286	287	288
##	0.000608044611701	0.637132094630353	0.001379765836737	0.407472061440141
##	289	290	291	292
##	0.000117960743233	0.011257579328480	0.000022875359931	0.000132622625720
##	293	294	295	296
##	0.000427911782653	0.015923920269599	0.000008959464618	0.910560281146165
##	297	298	299	300
##	0.000001737298054	0.609632487119766	0.000073826232976	0.000338547873234
##	301	302	303	304
##	0.004439535866393	0.003950611381065	0.000022875359931	0.008926775471448
##	305	306	307	308
##	0.000003945288852	0.000768490840574	0.020044745440700	0.000083002889885
##	309	310	311	312
##	0.044389538108148	0.000083002889885	0.000093320105773	0.000211899117165
##	313	314	315	316
##	0.000768490840574	0.000041095330150	0.000301127110317	0.002202892109700
##	317	318	319	320
##	0.000046203698937	0.035444902856469	0.000104919611649	0.609632487119766
##	321	322	323	324
##	0.000018096601846	0.061929112851855	0.000540851641837	0.000188474600895
##	325	326	327	328
##	0.039676275595187	0.000025718947465	0.010025347461247	0.035444902856469
##	329	330	331	332
##	0.000000266496267	0.326086940330321	0.000380617106200	0.000093320105773
##	333			
##	0.000188474600895			



```
penguins_pred <- rep(0, 333)
penguins_pred[penguins_probs > 0.5] = 1

penguins_pred # prediction vector
```

##	[1]	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
##	[38]	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
##	[75]	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1
##	[112]	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
##	[149]	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
##	[186]	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
##	[223]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
##	[260]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
##	[297]	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

```
# now, let's combine this with our old data to see how we did!

# first, we'll do this the "hard way" like the textbook wants.
# Make a vector of the actual data
truth <- penguins_cleaned$adelie # truth vector (to compare with the prediction vector)

truth
```

[illegible]

- some VERY useful definitions:
  1. TPR (True Positive Rate), also called Recall or Sensitivity:  $TP / (TP + FN)$
  2. FPR (False Positive Rate), also called Fall-Out:  $FP / (FP + TN)$
  3. TNR (True Negative Rate), also called Specificity:  $TN / (TN + FP)$
  4. PPV (Positive Predicted Value), also called Precision:  $TP / (TP + FP)$
  5. Prevalence:  $P / (P + N)$

6. Accuracy:  $(TP + TN) / (P + N)$

```
# now put them in a table! this is the beginnings of a confusion matrix:
table(penguins_pred, truth)
```

```
##           truth
## penguins_pred  0   1
##              0 177   9
##              1  10 137
```

```
# some VERY useful definitions:
# TPR (True Positive Rate), also called Recall or Sensitivity: TP / (TP + FN)
# FPR (False Positive Rate), also called Fall-Out: FP / (FP + TN)
# TNR (True Negative Rate), also called Specificity: TN / (TN + FP)
# PPV (Positive Predicted Value), also called Precision: TP / (TP + FP)
# Prevalence: P / (P + N)
# Accuracy: (TP + TN) / (P + N)
```

```
accuracy = (137 + 177) / 333
accuracy
```

```
## [1] 0.9429429
```

```
# # -----
#
# Stop! Your turn. Calculate accuracy and TPR :)
#
# # -----

# So remember this is the *training* accuracy - and here is our training error!
1 - mean(penguins_pred == truth)
```

```
## [1] 0.05705706
```

```
# Let's split into a test and train and do this the proper way!
```

```
# This is the way we talked about in the past to make a 50% even break:
train <- sample(1:nrow(penguins_cleaned), nrow(penguins_cleaned) / 2)
test <- (-train)
```

```
# Now run your model again!
```

```
glm_train <- glm(adelie ~ ., family = binomial(link="logit"), data = penguins_cleaned, subset = train)
```

```
# And generate predictions on your test data ...
```

```
glm_preds <- predict(glm_train, penguins_cleaned[test,], type = "response")
```

```
# annnnnnd let's run that accuracy check again!
```

```
new_predictions <- rep(0,333)
new_predictions[glm_preds > 0.5] = 1
```

```
# now put them in a table! this is the beginnings of a confusion matrix:
```

```
xtab = table(new_predictions, truth)
xtab
```

```
##           truth
## new_predictions  0   1
##           0 103  64
##           1  84  82
```

```
# and our accuracy?
```

```
mean(new_predictions == truth)
```

```
## [1] 0.5555556
```

```
# now this is a *lot* more realistic!
```

```
# let's cheat and use the caret package to give us ALL SORTS of good information:
```

```
caret::confusionMatrix(xtab) # requires a table of predicted values and truth values (separate
```

```
## Confusion Matrix and Statistics
```

```
##
##           truth
## new_predictions  0   1
##           0 103  64
##           1  84  82
##
##           Accuracy : 0.5556
##           95% CI : (0.5004, 0.6097)
##      No Information Rate : 0.5616
##      P-Value [Acc > NIR] : 0.6095
##
##           Kappa : 0.1108
##
##  Mcnemar's Test P-Value : 0.1183
##
##           Sensitivity : 0.5508
##           Specificity : 0.5616
##      Pos Pred Value : 0.6168
##      Neg Pred Value : 0.4940
##           Prevalence : 0.5616
```

```
##          Detection Rate : 0.3093
##    Detection Prevalence : 0.5015
##          Balanced Accuracy : 0.5562
##
##          'Positive' Class : 0
##
```

```
# # -----
#
# Stop! Let's go back to the presentation!
#
# # -----

# alright :)
```

```
# # -----
#
# K-nearest neighbours
#
# # -----

# We will now perform KNN using the knn() function, which is part of the knn()
# class library. This function works rather differently from the other model fitting
# functions that we have encountered thus far. Rather than a two-step
# approach in which we first fit the model and then we use the model to make
# predictions, knn() forms predictions using a single command. The function
# requires four inputs.

#1. A matrix containing the predictors associated with the training data,
# labeled train.X below.

# 2. A matrix containing the predictors associated with the data for which
# we wish to make predictions, labeled test.X below.

# 3. A vector containing the class labels for the training observations,
# labeled train.Direction below.

# 4. A value for K, the number of nearest neighbors to be used by the
# classifier.
```

```
# So let's go back to our penguin data. You are super lucky, you managed to dry the paperwork
# and recover one of the other variables - body mass! So we're going to use those two data points
# try and predict which species these penguins were

# new data:
```

```
knn_penguins <-
```

```

penguins %>%
drop_na() %>%
select(species, bill_length_mm, body_mass_g)

# new test and control splits

train <- sample(1:nrow(knn_penguins), nrow(knn_penguins) / 2)
test <- (-train)

# let's make our data for above!

train.X <- cbind(knn_penguins$bill_length_mm, knn_penguins$body_mass_g)[train,]
test.X <- cbind(knn_penguins$bill_length_mm, knn_penguins$body_mass_g)[test,]
train.species <- knn_penguins$species[train]
# we'll also go ahead and make a test.species, "ground truth", vector
test.species <- knn_penguins$species[test]
k <- 3 # this is arbitrary, we should try for different values

# okay, let's make our model!

set.seed(1)
knn.pred <- knn(train.X, test.X, train.species, k = k)

# what does this model object look like?

knn.pred

```

```

## [1] Adelie Chinstrap Adelie Gentoo Adelie Gentoo Adelie
## [8] Adelie Gentoo Adelie Chinstrap Adelie Adelie Adelie
## [15] Gentoo Adelie Adelie Adelie Adelie Adelie Gentoo
## [22] Gentoo Adelie Adelie Adelie Adelie Adelie Adelie
## [29] Gentoo Chinstrap Chinstrap Chinstrap Chinstrap Adelie Adelie
## [36] Chinstrap Adelie Adelie Chinstrap Adelie Adelie Adelie
## [43] Adelie Gentoo Adelie Chinstrap Adelie Chinstrap Gentoo
## [50] Adelie Adelie Gentoo Adelie Gentoo Gentoo Adelie
## [57] Adelie Gentoo Adelie Adelie Adelie Adelie Chinstrap
## [64] Chinstrap Adelie Adelie Adelie Adelie Adelie Adelie Gentoo
## [71] Adelie Adelie Adelie Chinstrap Adelie Adelie Adelie
## [78] Adelie Adelie Adelie Adelie Adelie Adelie Gentoo
## [85] Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo
## [92] Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo
## [99] Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo
## [106] Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo
## [113] Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo
## [120] Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo
## [127] Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo Gentoo
## [134] Gentoo Gentoo Gentoo Gentoo Gentoo Chinstrap Adelie

```

```
## [141] Adelie      Adelie      Chinstrap Adelie      Chinstrap Chinstrap Adelie
## [148] Adelie      Adelie      Adelie      Adelie      Adelie      Adelie      Chinstrap
## [155] Gentoo      Chinstrap Adelie      Adelie      Adelie      Gentoo      Chinstrap
## [162] Adelie      Chinstrap Chinstrap Chinstrap Chinstrap Chinstrap
## Levels: Adelie Chinstrap Gentoo
```

```
summary(knn.pred)
```

```
##      Adelie Chinstrap      Gentoo
##         71         25         71
```

```
# how'd we do?
```

```
knn_table <- table(knn.pred, test.species)
knn_table
```

```
##              test.species
## knn.pred      Adelie Chinstrap Gentoo
##   Adelie         55         15      1
##   Chinstrap      13         12      0
##   Gentoo         14          2     55
```

```
# what's the accuracy?
```

```
mean(knn.pred == test.species)
```

```
## [1] 0.7305389
```

```
# not too bad!
```

```
# why don't we compare this SAME task to a logistic regression?
```

```
# THIS IS A MULTIVARIATE LOGISTIC REGRESSION.
```

```
# to make this easier, we're going to load a new package!
```

```
library(nnet)
```

```
# and from this package, we're gonna use a fancy new function called "multinom"
multi_class_logit <- multinom(species ~ ., data = knn_penguins, subset = train)
```

```
## # weights: 12 (6 variable)
## initial value 182.369640
## iter 10 value 31.877399
## iter 20 value 18.028107
## iter 30 value 15.745352
## iter 40 value 15.230940
## final value 15.230933
## converged
```

```
logit_pred <- predict(multi_class_logit, newdata=knn_penguins[test,], "class")
```

```
# Let's make a table!
```

```
logit_table <- table(knn_penguins$species[test], logit_pred)
```

```
logit_table
```

```
##           logit_pred
##           Adelie Chinstrap Gentoo
## Adelie           71           6           5
## Chinstrap          0          29           0
## Gentoo             1           1          54
```

```
# So the logit model is actually much better!
```

```
mean(logit_pred == knn_penguins$species[test])
```

```
## [1] 0.9221557
```

```
# # -----
#
# Coding Project!
#
# # -----
```

```
# Check the Google Drive. I've created a file called spotify_labels.csv. Download it.
```

```
# This contains a dataset (13795 x 15) of songs from Spotify that are labeled as one of four g
```

```
# hip hop, indie, metal, or pop.
```

```
# Your job is to use some of the proprietary "scores" from Spotify to see if you can build a m
```

```
# that accurately guesses the right label! Try out any approach you want from today (knn or lo
```

```
# and feel free to manipulate the variables as much as you want to generate a more accurate mo
```

```
spotify <- read_csv("w4 data/spotify_labels.csv")
```

```
## Rows: 13795 Columns: 15
```

```
## -- Column specification -----
```

```
## Delimiter: ","
```

```
## chr (2): label, artist_name
```

```
## dbl (13): danceability, energy, key, loudness, mode, speechiness, acousticne...
```

```
##
```

```
## i Use 'spec()' to retrieve the full column specification for this data.
```

```
## i Specify the column types or set 'show_col_types = FALSE' to quiet this message.
```

```
head(spotify)
```

```
## # A tibble: 6 x 15
##   label artist_name      danceability energy   key loudness  mode speechiness
##   <chr> <chr>          <dbl>   <dbl> <dbl>   <dbl> <dbl>      <dbl>
## 1 metal Myrkur          0.24    0.313   5    -11.5     1      0.033
## 2 metal Monuments       0.445    0.968   6     -2.56    1      0.207
## 3 metal The Southern Oracle 0.51    0.989   1     -3.66    0      0.376
## 4 metal Insomnium        0.498    0.833   7     -8.87    0      0.0405
## 5 metal Galleons         0.471    0.925   7     -4.63    1      0.0598
## 6 metal Powerwolf         0.463    0.962   1     -5.70    0      0.0712
## # ... with 7 more variables: acousticness <dbl>, instrumentalness <dbl>,
## #   liveness <dbl>, valence <dbl>, tempo <dbl>, duration_ms <dbl>,
## #   time_signature <dbl>
```

```
colnames(spotify)
```

```
## [1] "label"          "artist_name"    "danceability"   "energy"
## [5] "key"            "loudness"       "mode"           "speechiness"
## [9] "acousticness"   "instrumentalness" "liveness"       "valence"
## [13] "tempo"          "duration_ms"    "time_signature"
```

```
# new data:
```

```
spotify <-
  spotify %>%
  drop_na() %>%
  select(-artist_name) %>%
  mutate(mode = as.factor(mode),
         key = as.factor(key),
         time_signature = as.factor(time_signature))
```

```
# new test and control splits (index values)
```

```
train <- sample(1:nrow(spotify), nrow(spotify) / 2)
test <- (-train)
```

```
# let's make our data for above!
```

```
# to make sense in a 2d plot, you need to make you knn use two variables, so you
# can take two variables, or pca the data set and do knn on two principal components.
```

```
train.X <- cbind(spotify$danceability, spotify$speechiness, spotify$valence, spotify$loudness)
test.X <- cbind(spotify$danceability, spotify$speechiness, spotify$valence, spotify$loudness)[
```



```

train.labels <- spotify$label[train]

# we'll also go ahead and make a test.species, "ground truth", vector
test.labels <- spotify$label[test]
k <- 3 # this is arbitrary, we should try for different values

# okay, let's make our model!

set.seed (1)
knn.pred <- knn(train.X, test.X, train.labels , k = k)

# what does this model object look like?

knn.pred

```

```

##      [1] indie  metal  indie  metal  metal  metal  metal  metal  metal  indie  metal
##     [11] metal  indie  indie  indie  pop    indie  metal  indie  indie  metal  metal
##     [21] indie  indie  metal  pop    indie  metal  metal  indie  pop    pop    metal
##     [31] indie  indie  metal  metal  metal  pop    metal  pop    metal  metal  metal
##     [41] metal  metal  indie  metal  hiphop metal  metal  pop    metal  indie
##     [51] pop    metal  metal  metal  indie  metal  metal  metal  metal  metal  metal
##     [61] indie  indie  metal  metal  metal  metal  metal  indie  metal  pop
##     [71] metal  indie  metal  metal  metal  metal  metal  metal  metal  pop
##     [81] metal  indie  indie  metal  indie  indie  metal  metal  pop    indie
##     [91] metal  indie  metal  metal  metal  metal  metal  metal  metal  pop
##    [101] metal  pop    metal  metal  metal  metal  pop    metal  metal  metal
##    [111] metal  indie  metal  metal  pop    pop    metal  metal  metal  pop
##    [121] metal  indie  metal  metal  metal  indie  pop    metal  metal  metal
##    [131] metal  metal  metal  metal  pop    metal  metal  metal  metal  metal
##    [141] metal  indie  indie  metal  metal  metal  metal  pop    hiphop metal
##    [151] metal  metal  metal  metal  metal  metal  indie  metal  metal  metal
##    [161] indie  metal  indie  metal  indie  indie  pop    pop    pop    metal
##    [171] metal  metal  metal  pop    metal  metal  indie  pop    pop    metal
##    [181] metal  indie  metal  metal  indie  indie  indie  pop    metal  metal
##    [191] pop    indie  indie  indie  metal  indie  indie  pop    metal  indie
##    [201] metal  metal  pop    indie  metal  metal  metal  indie  metal  indie
##    [211] metal  metal  metal  metal  metal  indie  metal  metal  metal  pop
##    [221] metal  metal  indie  indie  metal  pop    metal  indie  metal  metal
##    [231] metal  indie  metal  metal  metal  metal  metal  pop    metal  metal
##    [241] indie  metal  indie  metal  metal  metal  pop    pop    pop    indie
##    [251] metal  metal  metal  metal  metal  indie  indie  metal  metal  metal
##    [261] pop    metal  metal  pop    metal  metal  hiphop metal  metal  indie
##    [271] metal  metal  indie  metal  pop    metal  metal  metal  metal  metal
##    [281] metal  metal  metal  metal  metal  metal  metal  metal  metal  metal
##    [291] metal  indie  metal  indie  metal  indie  metal  metal  indie  pop
##    [301] metal  metal  indie  metal  metal  indie  metal  indie  indie  indie
##    [311] pop    pop    metal  metal  metal  metal  metal  metal  metal  metal

```

##	[321]	metal	metal	indie	metal	metal	metal	metal	metal	metal	pop
##	[331]	metal	metal	indie	hiphop	indie	metal	indie	indie	metal	metal
##	[341]	indie	indie	indie	metal	pop	metal	indie	metal	indie	metal
##	[351]	indie	indie	indie	pop	metal	pop	indie	metal	metal	metal
##	[361]	pop	indie	metal	metal	metal	pop	metal	metal	metal	metal
##	[371]	pop	metal	pop	metal	indie	indie	metal	indie	metal	metal
##	[381]	metal	metal	pop	indie	metal	metal	metal	metal	metal	metal
##	[391]	metal	metal	metal	metal	indie	metal	metal	indie	metal	indie
##	[401]	metal	indie	metal	metal	metal	pop	metal	metal	metal	indie
##	[411]	metal	indie	metal	metal	metal	indie	metal	metal	metal	metal
##	[421]	indie	pop	metal	pop	metal	metal	metal	metal	metal	indie
##	[431]	pop	pop	indie	indie	metal	metal	metal	indie	pop	metal
##	[441]	metal	indie	indie	metal	metal	metal	metal	metal	metal	metal
##	[451]	pop	pop	metal	indie	indie	metal	indie	metal	metal	metal
##	[461]	metal	indie	pop	metal	indie	indie	pop	metal	metal	indie
##	[471]	metal	metal	pop	indie	metal	metal	metal	indie	metal	metal
##	[481]	metal	indie	metal	metal	metal	metal	metal	metal	metal	indie
##	[491]	metal	metal	metal	metal	hiphop	metal	pop	metal	indie	metal
##	[501]	metal	metal	pop	metal	metal	indie	metal	indie	metal	metal
##	[511]	metal	metal	pop	metal	indie	metal	metal	metal	metal	metal
##	[521]	metal	pop	metal	metal	metal	indie	metal	metal	metal	indie
##	[531]	metal	metal	indie	indie	metal	indie	metal	pop	metal	pop
##	[541]	metal	indie	indie	indie	metal	metal	indie	metal	pop	pop
##	[551]	metal	metal	metal	metal	metal	metal	metal	indie	indie	metal
##	[561]	metal	metal	pop	metal	metal	hiphop	metal	metal	metal	metal
##	[571]	indie	pop	indie	metal	metal	metal	hiphop	metal	metal	metal
##	[581]	indie	indie	indie	indie	metal	metal	metal	indie	metal	indie
##	[591]	metal	indie	metal	indie	metal	metal	metal	indie	indie	metal
##	[601]	indie	metal	pop	metal	indie	indie	metal	indie	metal	metal
##	[611]	pop	indie	metal	pop	metal	hiphop	metal	indie	indie	indie
##	[621]	indie	indie	pop	metal	hiphop	metal	pop	metal	metal	indie
##	[631]	pop	indie	metal	indie	pop	pop	pop	pop	metal	indie
##	[641]	metal	pop	metal	indie	indie	metal	metal	metal	metal	indie
##	[651]	indie	pop	indie	metal	metal	metal	indie	metal	pop	metal
##	[661]	metal	indie	pop	metal	indie	metal	indie	pop	metal	metal
##	[671]	metal	indie	metal	metal	metal	indie	metal	metal	metal	metal
##	[681]	pop	hiphop	metal	indie	metal	metal	metal	indie	metal	metal
##	[691]	metal	metal	indie	metal	metal	pop	metal	metal	metal	metal
##	[701]	metal	pop	metal	indie	metal	pop	pop	hiphop	metal	metal
##	[711]	pop	metal	metal	metal	pop	metal	metal	metal	metal	pop
##	[721]	pop	indie	pop	indie	indie	metal	metal	pop	metal	metal
##	[731]	indie	metal	metal	pop	indie	metal	metal	metal	indie	pop
##	[741]	metal	metal	metal	indie	metal	metal	metal	metal	metal	indie
##	[751]	metal	metal	metal	metal	indie	metal	metal	indie	metal	indie
##	[761]	indie	metal	metal	metal	metal	pop	metal	indie	metal	metal
##	[771]	metal	pop	metal	metal	metal	pop	metal	metal	pop	pop
##	[781]	metal	indie	indie	metal	metal	indie	pop	metal	indie	metal
##	[791]	pop	metal	indie	indie	metal	pop	pop	metal	metal	indie

##	[801]	pop	metal	metal	pop	indie	metal	indie	indie	pop	metal
##	[811]	indie	metal	metal	indie	metal	metal	metal	indie	metal	metal
##	[821]	metal	indie	indie	pop	metal	metal	metal	metal	metal	indie
##	[831]	indie	metal	metal	indie	indie	indie	indie	indie	metal	metal
##	[841]	indie	metal	metal	metal	metal	metal	indie	metal	metal	metal
##	[851]	indie	pop	indie	metal	metal	pop	metal	pop	metal	pop
##	[861]	pop	indie	indie	metal	metal	metal	metal	pop	indie	metal
##	[871]	metal	metal	indie	metal	metal	metal	indie	metal	metal	indie
##	[881]	metal	hiphop	metal	metal	metal	metal	metal	metal	metal	metal
##	[891]	indie	pop	metal	indie	metal	metal	pop	pop	metal	pop
##	[901]	metal	metal	indie	metal	metal	metal	metal	metal	indie	indie
##	[911]	indie	indie	hiphop	metal	indie	indie	indie	pop	metal	metal
##	[921]	pop	metal	metal	metal	metal	metal	metal	pop	hiphop	metal
##	[931]	indie	indie	metal	pop	metal	metal	indie	metal	metal	indie
##	[941]	indie	indie	metal	metal	pop	metal	metal	metal	metal	metal
##	[951]	metal	indie	indie	pop	metal	indie	indie	metal	pop	metal
##	[961]	indie	indie	indie	pop	metal	indie	pop	metal	indie	metal
##	[971]	pop	hiphop	pop	metal	metal	indie	metal	indie	indie	metal
##	[981]	metal	metal	metal	indie	metal	pop	indie	metal	metal	pop
##	[991]	metal	metal	metal	metal	hiphop	metal	metal	indie	metal	metal
##	[1001]	indie	metal	indie	metal	indie	metal	metal	metal	metal	metal
##	[1011]	indie	metal	metal	indie	metal	metal	metal	indie	metal	metal
##	[1021]	indie	metal	metal	indie	indie	metal	metal	indie	indie	metal
##	[1031]	metal	metal	metal	metal	indie	metal	metal	indie	pop	indie
##	[1041]	indie	metal	metal	indie	metal	metal	metal	metal	metal	metal
##	[1051]	metal	metal	metal	metal	metal	metal	metal	metal	indie	metal
##	[1061]	indie	indie	pop	metal	indie	indie	indie	metal	metal	metal
##	[1071]	metal	indie	metal	metal	indie	indie	indie	pop	metal	metal
##	[1081]	metal	indie	indie	indie	pop	indie	indie	indie	metal	hiphop
##	[1091]	indie	metal	metal	indie	metal	metal	indie	metal	metal	indie
##	[1101]	metal	indie	metal	indie	indie	metal	indie	metal	metal	indie
##	[1111]	pop	metal	metal	metal	indie	metal	metal	metal	metal	metal
##	[1121]	metal	indie	metal	indie	metal	metal	metal	pop	metal	pop
##	[1131]	metal	metal	metal	indie	metal	metal	pop	indie	metal	indie
##	[1141]	pop	pop	indie	metal	metal	pop	indie	metal	hiphop	metal
##	[1151]	pop	metal	metal	pop	metal	metal	metal	pop	metal	metal
##	[1161]	metal	metal	pop	metal	metal	metal	pop	metal	metal	indie
##	[1171]	metal	pop	pop	indie	metal	pop	metal	indie	metal	pop
##	[1181]	indie	pop	pop	metal	metal	metal	metal	indie	indie	metal
##	[1191]	metal	metal	pop	metal	indie	indie	metal	metal	indie	indie
##	[1201]	indie	metal	metal	metal	pop	metal	metal	metal	metal	indie
##	[1211]	metal	indie	metal	metal	metal	metal	metal	pop	metal	metal
##	[1221]	pop	indie	pop	metal	metal	metal	metal	metal	indie	metal
##	[1231]	metal	indie	metal	metal	indie	indie	indie	metal	metal	metal
##	[1241]	metal	metal	metal	metal	metal	indie	metal	metal	metal	indie
##	[1251]	metal	indie	metal	indie	metal	metal	pop	metal	metal	metal
##	[1261]	metal	indie	metal	metal	metal	pop	indie	pop	metal	metal
##	[1271]	pop	metal	pop	metal	hiphop	metal	indie	indie	metal	indie

##	[1281]	indie	indie	metal	metal	metal	metal	metal	metal	metal	indie
##	[1291]	metal	metal	metal	metal	pop	pop	metal	metal	metal	metal
##	[1301]	pop	pop	metal	pop	metal	metal	metal	metal	metal	indie
##	[1311]	pop	pop	metal	metal	metal	metal	metal	pop	indie	metal
##	[1321]	metal	metal	metal	indie	metal	metal	pop	pop	indie	metal
##	[1331]	metal	indie	indie	metal	indie	indie	indie	metal	metal	metal
##	[1341]	metal	indie	metal	metal	metal	metal	metal	indie	metal	metal
##	[1351]	metal	indie	metal	metal	indie	metal	metal	metal	pop	indie
##	[1361]	metal	indie	metal	indie	metal	metal	metal	indie	metal	metal
##	[1371]	indie	metal	pop	indie	metal	pop	metal	metal	metal	metal
##	[1381]	metal	hiphop	metal	pop	metal	metal	pop	metal	metal	metal
##	[1391]	indie	indie	indie	indie	pop	metal	indie	metal	metal	indie
##	[1401]	metal	metal	metal	metal	metal	pop	metal	pop	metal	metal
##	[1411]	metal	metal	indie	metal	metal	indie	indie	metal	metal	metal
##	[1421]	metal	metal	indie	indie	indie	pop	metal	metal	metal	metal
##	[1431]	metal	metal	metal	metal	metal	pop	metal	indie	metal	metal
##	[1441]	metal	metal	metal	metal	metal	metal	metal	metal	metal	indie
##	[1451]	indie	metal	metal	metal	pop	indie	pop	metal	metal	metal
##	[1461]	metal	metal	metal	metal	hiphop	metal	pop	metal	indie	pop
##	[1471]	metal	metal	indie	metal	indie	pop	metal	metal	pop	metal
##	[1481]	indie	indie	metal	indie	metal	pop	metal	metal	indie	indie
##	[1491]	indie	metal	metal	indie	metal	indie	metal	metal	metal	metal
##	[1501]	indie	indie	metal	metal	metal	metal	metal	metal	hiphop	hiphop
##	[1511]	indie	hiphop	hiphop	pop	pop	pop	indie	pop	indie	pop
##	[1521]	indie	pop	indie	hiphop	hiphop	indie	hiphop	pop	indie	indie
##	[1531]	hiphop	hiphop	hiphop	pop	hiphop	hiphop	hiphop	hiphop	hiphop	pop
##	[1541]	pop	hiphop	hiphop	pop	pop	hiphop	pop	pop	hiphop	hiphop
##	[1551]	hiphop	hiphop	hiphop	metal	hiphop	hiphop	pop	hiphop	pop	hiphop
##	[1561]	hiphop	pop	hiphop	hiphop	hiphop	hiphop	hiphop	hiphop	hiphop	hiphop
##	[1571]	hiphop	hiphop	hiphop	pop	hiphop	pop	pop	hiphop	pop	hiphop
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##	[4471]	metal	metal	indie	metal	indie	indie	metal	hiphop	pop	indie
##	[4481]	pop	indie	indie	indie	indie	pop	metal	metal	metal	pop
##	[4491]	indie	indie	hiphop	metal	hiphop	indie	pop	pop	hiphop	indie
##	[4501]	indie	indie	pop	indie	indie	indie	indie	pop	indie	metal
##	[4511]	metal	pop	pop	hiphop	indie	metal	indie	metal	hiphop	indie
##	[4521]	pop	indie	indie	pop	indie	hiphop	indie	hiphop	indie	pop
##	[4531]	pop	indie	indie	indie	indie	pop	indie	hiphop	indie	pop
##	[4541]	metal	hiphop	indie	indie	indie	metal	indie	indie	indie	metal
##	[4551]	metal	indie	indie	metal	indie	indie	pop	indie	metal	pop
##	[4561]	metal	metal	pop	pop	hiphop	pop	metal	indie	pop	indie
##	[4571]	indie	indie	indie	metal	pop	hiphop	pop	pop	metal	metal
##	[4581]	indie	pop	metal	hiphop	indie	pop	pop	indie	pop	indie
##	[4591]	metal	metal	indie	pop	indie	hiphop	metal	pop	indie	metal
##	[4601]	indie	indie	hiphop	metal	pop	metal	metal	indie	metal	pop
##	[4611]	indie	pop	pop	metal	pop	indie	indie	indie	indie	indie
##	[4621]	indie	indie	indie	indie	indie	pop	indie	indie	indie	hiphop
##	[4631]	metal	metal	indie	indie	indie	indie	indie	metal	indie	indie

##	[4641]	pop	metal	metal	indie	indie	hiphop	pop	pop	indie	pop
##	[4651]	indie	indie	metal	indie	indie	metal	pop	pop	pop	indie
##	[4661]	pop	indie	pop	metal	indie	indie	pop	pop	indie	metal
##	[4671]	indie	metal	metal	pop	hiphop	pop	pop	indie	indie	pop
##	[4681]	pop	pop	indie	metal	indie	metal	hiphop	indie	pop	indie
##	[4691]	indie	pop	metal	indie	indie	indie	indie	indie	indie	indie
##	[4701]	indie	metal	hiphop	indie	metal	metal	hiphop	pop	indie	indie
##	[4711]	indie	indie	indie	indie	pop	metal	pop	hiphop	indie	pop
##	[4721]	metal	pop	pop	pop	hiphop	indie	pop	indie	indie	metal
##	[4731]	indie	metal	indie	indie	indie	pop	indie	metal	indie	pop
##	[4741]	indie	indie	pop	indie	pop	indie	indie	pop	indie	indie
##	[4751]	indie	indie	pop	indie	indie	indie	indie	pop	hiphop	indie
##	[4761]	indie	metal	indie	indie	pop	pop	metal	indie	indie	hiphop
##	[4771]	indie	indie	pop	indie	indie	indie	hiphop	indie	indie	pop
##	[4781]	pop	indie	indie	metal	indie	indie	indie	metal	indie	hiphop
##	[4791]	pop	metal	indie	indie	indie	metal	metal	indie	indie	indie
##	[4801]	indie	indie	pop	pop	indie	indie	metal	indie	pop	indie
##	[4811]	pop	pop	metal	metal	pop	indie	pop	metal	metal	pop
##	[4821]	metal	indie	metal	indie	indie	metal	indie	indie	metal	indie
##	[4831]	indie	indie	indie	indie	pop	indie	indie	pop	indie	pop
##	[4841]	hiphop	pop	indie	metal	indie	pop	pop	metal	indie	metal
##	[4851]	pop	indie	indie	indie	indie	indie	indie	metal	pop	pop
##	[4861]	indie	metal	pop	indie	indie	metal	indie	indie	pop	pop
##	[4871]	pop	indie	indie	indie	hiphop	pop	metal	metal	indie	metal
##	[4881]	indie	pop	hiphop	metal	indie	indie	metal	metal	indie	indie
##	[4891]	pop	indie	indie	indie	indie	indie	indie	pop	hiphop	indie
##	[4901]	indie	pop	metal	indie	metal	metal	indie	indie	pop	indie
##	[4911]	pop	pop	metal	hiphop	indie	indie	indie	indie	pop	pop
##	[4921]	indie	hiphop	indie	metal	pop	pop	pop	indie	indie	indie
##	[4931]	indie	pop	hiphop	indie	pop	indie	hiphop	metal	metal	metal
##	[4941]	metal	metal	metal	metal	metal	hiphop	indie	pop	indie	metal
##	[4951]	pop	indie	pop	indie	pop	pop	indie	pop	indie	indie
##	[4961]	indie	metal	metal	pop	hiphop	metal	hiphop	pop	indie	indie
##	[4971]	pop	indie	indie	hiphop	pop	pop	metal	pop	indie	pop
##	[4981]	hiphop	indie	indie	metal	pop	indie	metal	hiphop	indie	pop
##	[4991]	pop	pop	indie	indie	indie	indie	metal	metal	indie	metal
##	[5001]	metal	indie	indie	pop	pop	pop	indie	metal	hiphop	pop
##	[5011]	indie	hiphop	indie	metal	metal	indie	pop	indie	indie	indie
##	[5021]	indie	indie	indie	metal	metal	pop	indie	pop	metal	indie
##	[5031]	indie	indie	pop	indie	indie	metal	indie	metal	pop	pop
##	[5041]	pop	hiphop	hiphop	indie	hiphop	indie	pop	indie	pop	pop
##	[5051]	pop	pop	pop	indie	pop	pop	indie	indie	pop	pop
##	[5061]	hiphop	pop	indie	indie	hiphop	pop	hiphop	hiphop	pop	hiphop
##	[5071]	pop	pop	indie	pop	indie	indie	pop	pop	hiphop	pop
##	[5081]	pop	indie	indie	indie	pop	pop	indie	pop	indie	indie
##	[5091]	pop	pop	pop	metal	pop	pop	pop	hiphop	pop	metal
##	[5101]	hiphop	indie	indie	pop	pop	pop	pop	pop	pop	hiphop
##	[5111]	indie	indie	indie	pop	pop	pop	metal	pop	hiphop	metal

##	[5121]	pop	indie	metal	metal	pop	pop	indie	metal	indie	pop
##	[5131]	indie	pop	indie	pop	pop	pop	pop	indie	indie	hiphop
##	[5141]	indie	pop	indie	pop	hiphop	pop	pop	metal	indie	pop
##	[5151]	pop	indie	pop	pop	indie	metal	indie	hiphop	metal	pop
##	[5161]	pop	metal	hiphop	metal	pop	indie	indie	metal	pop	pop
##	[5171]	metal	indie	indie	pop	indie	pop	pop	pop	pop	pop
##	[5181]	pop	hiphop	indie	indie	hiphop	indie	pop	indie	indie	indie
##	[5191]	pop	pop	pop	hiphop	indie	indie	pop	pop	indie	metal
##	[5201]	indie	indie	indie	indie	indie	indie	indie	pop	hiphop	pop
##	[5211]	indie	hiphop	pop	pop	indie	pop	indie	pop	indie	hiphop
##	[5221]	indie	hiphop	pop	hiphop	pop	pop	hiphop	indie	pop	pop
##	[5231]	pop	indie	metal	metal	indie	indie	metal	pop	metal	pop
##	[5241]	pop	indie	indie	pop	pop	indie	indie	indie	metal	hiphop
##	[5251]	pop	pop	hiphop	pop	pop	indie	metal	indie	pop	indie
##	[5261]	indie	hiphop	pop	hiphop	indie	indie	indie	indie	pop	hiphop
##	[5271]	pop	indie	pop	hiphop	metal	indie	metal	pop	pop	pop
##	[5281]	indie	metal	pop	pop	pop	pop	indie	pop	hiphop	indie
##	[5291]	indie	pop	indie	pop	indie	pop	hiphop	indie	pop	hiphop
##	[5301]	pop	pop	metal	pop	metal	pop	hiphop	metal	pop	indie
##	[5311]	indie	pop	indie	pop	indie	pop	indie	indie	pop	indie
##	[5321]	pop	pop	indie	metal	hiphop	metal	pop	pop	pop	indie
##	[5331]	indie	indie	metal	indie	pop	pop	pop	pop	indie	indie
##	[5341]	hiphop	pop	hiphop	pop	metal	pop	pop	pop	indie	indie
##	[5351]	hiphop	hiphop	metal	pop	pop	indie	pop	indie	pop	indie
##	[5361]	pop	pop	pop	indie	indie	pop	metal	pop	metal	pop
##	[5371]	indie	hiphop	pop	hiphop	metal	pop	pop	indie	pop	indie
##	[5381]	hiphop	pop	metal	pop	pop	pop	pop	indie	indie	indie
##	[5391]	indie	pop	pop	pop	metal	hiphop	hiphop	metal	indie	indie
##	[5401]	hiphop	pop	indie	indie	pop	indie	pop	indie	indie	hiphop
##	[5411]	indie	pop	indie	metal	hiphop	pop	pop	pop	pop	pop
##	[5421]	pop	pop	indie	pop	pop	metal	indie	pop	pop	metal
##	[5431]	hiphop	indie	pop	indie	metal	indie	metal	hiphop	pop	indie
##	[5441]	pop	pop	indie	hiphop	indie	metal	pop	metal	metal	indie
##	[5451]	pop	pop	pop	pop	pop	hiphop	pop	indie	metal	pop
##	[5461]	pop	pop	metal	pop	metal	indie	pop	indie	indie	indie
##	[5471]	indie	pop	indie	metal	indie	indie	hiphop	indie	pop	pop
##	[5481]	indie	pop	pop	pop	indie	hiphop	indie	indie	pop	metal
##	[5491]	indie	pop	pop	hiphop	indie	hiphop	indie	indie	pop	pop
##	[5501]	pop	indie	indie	pop	pop	indie	indie	pop	pop	pop
##	[5511]	hiphop	indie	hiphop	indie	hiphop	hiphop	pop	pop	pop	pop
##	[5521]	indie	hiphop	pop	indie	hiphop	pop	metal	indie	metal	metal
##	[5531]	indie	indie	pop	pop	pop	pop	indie	indie	pop	indie
##	[5541]	indie	indie	hiphop	indie	pop	pop	metal	metal	metal	indie
##	[5551]	pop	metal	pop	pop	metal	indie	hiphop	indie	pop	indie
##	[5561]	indie	indie	pop	pop	indie	pop	pop	indie	pop	hiphop
##	[5571]	hiphop	pop	indie	pop	pop	indie	pop	pop	pop	pop
##	[5581]	pop	hiphop	pop	indie	indie	indie	pop	pop	pop	pop
##	[5591]	pop	indie	metal	hiphop	pop	indie	pop	metal	pop	pop

##	[5601]	indie	metal	metal	indie	pop	pop	pop	pop	pop	metal
##	[5611]	metal	indie	pop	pop	metal	indie	pop	pop	hiphop	indie
##	[5621]	pop	pop	indie	pop	pop	pop	pop	indie	pop	pop
##	[5631]	pop	indie	pop	indie	indie	pop	pop	metal	indie	metal
##	[5641]	indie	indie	hiphop	pop	hiphop	pop	pop	indie	hiphop	indie
##	[5651]	pop	pop	metal	indie	pop	pop	pop	indie	metal	hiphop
##	[5661]	indie	hiphop	pop	indie	pop	indie	pop	hiphop	indie	pop
##	[5671]	pop	indie	pop	pop	pop	hiphop	pop	pop	metal	pop
##	[5681]	metal	indie	hiphop	pop	metal	metal	indie	metal	pop	indie
##	[5691]	metal	metal	pop	indie	metal	pop	indie	indie	metal	metal
##	[5701]	hiphop	pop	pop	pop	hiphop	pop	hiphop	indie	pop	pop
##	[5711]	pop	pop	indie	indie	pop	hiphop	pop	pop	pop	indie
##	[5721]	pop	pop	indie	pop	pop	pop	pop	pop	pop	hiphop
##	[5731]	pop	pop	pop	pop	indie	indie	pop	indie	indie	pop
##	[5741]	pop	indie	pop	pop	hiphop	pop	indie	indie	pop	pop
##	[5751]	pop	indie	pop	indie	indie	metal	pop	pop	pop	metal
##	[5761]	indie	hiphop	hiphop	hiphop	indie	pop	metal	indie	indie	pop
##	[5771]	hiphop	pop	metal	metal	pop	indie	hiphop	indie	metal	indie
##	[5781]	pop	pop	indie	indie	hiphop	metal	pop	indie	hiphop	indie
##	[5791]	hiphop	pop	metal	pop	pop	indie	indie	indie	pop	metal
##	[5801]	hiphop	indie	pop	pop	hiphop	pop	pop	indie	pop	metal
##	[5811]	indie	indie	indie	pop	pop	indie	pop	pop	metal	indie
##	[5821]	indie	pop	pop	indie	pop	metal	pop	pop	pop	pop
##	[5831]	hiphop	pop	pop	indie	pop	pop	indie	pop	pop	pop
##	[5841]	pop	indie	indie	pop	indie	indie	pop	metal	indie	pop
##	[5851]	pop	pop	hiphop	indie	pop	hiphop	hiphop	pop	metal	indie
##	[5861]	indie	pop	pop	metal	indie	hiphop	metal	hiphop	pop	pop
##	[5871]	hiphop	pop	pop	indie	indie	indie	pop	pop	pop	pop
##	[5881]	indie	indie	pop	indie	pop	pop	pop	indie	indie	indie
##	[5891]	indie	pop	pop	pop	pop	pop	pop	pop	indie	metal
##	[5901]	indie	metal	pop	pop	metal	pop	pop	indie	hiphop	indie
##	[5911]	indie	pop	indie	pop	pop	indie	hiphop	indie	pop	pop
##	[5921]	pop	pop	hiphop	hiphop	indie	hiphop	indie	hiphop	pop	hiphop
##	[5931]	pop	pop	pop	pop	pop	indie	indie	metal	pop	indie
##	[5941]	pop	indie	indie	indie	indie	indie	indie	pop	pop	pop
##	[5951]	pop	indie	pop	pop	indie	pop	metal	hiphop	pop	pop
##	[5961]	pop	pop	pop	pop	pop	metal	metal	indie	indie	indie
##	[5971]	pop	pop	hiphop	indie	indie	indie	indie	pop	hiphop	pop
##	[5981]	pop	metal	indie	pop	pop	hiphop	metal	pop	indie	indie
##	[5991]	pop	pop	pop	metal	indie	pop	pop	indie	indie	indie
##	[6001]	indie	hiphop	pop	indie	hiphop	pop	indie	pop	pop	indie
##	[6011]	indie	indie	pop	hiphop	indie	indie	indie	indie	indie	pop
##	[6021]	pop	pop	indie	metal	hiphop	indie	indie	pop	metal	pop
##	[6031]	metal	pop	indie	metal	pop	indie	hiphop	pop	metal	hiphop
##	[6041]	indie	indie	pop	indie	pop	indie	pop	pop	pop	indie
##	[6051]	indie	hiphop	hiphop	metal	metal	pop	indie	metal	pop	pop
##	[6061]	pop	indie	metal	indie	indie	indie	pop	indie	hiphop	hiphop
##	[6071]	pop	indie	pop	indie	indie	indie	pop	pop	indie	indie

##	[6081]	hiphop	pop	pop	pop	pop	pop	pop	indie	pop	indie
##	[6091]	indie	pop	indie	pop	pop	metal	indie	pop	pop	metal
##	[6101]	pop	pop	pop	indie	pop	pop	pop	indie	indie	metal
##	[6111]	pop	pop	indie	pop	pop	indie	pop	pop	indie	hiphop
##	[6121]	pop	hiphop	indie	indie	hiphop	pop	hiphop	pop	hiphop	indie
##	[6131]	pop	indie	pop	indie	indie	pop	indie	pop	pop	indie
##	[6141]	indie	pop	indie	indie	metal	hiphop	pop	indie	pop	hiphop
##	[6151]	pop	metal	pop	indie	pop	hiphop	indie	metal	pop	pop
##	[6161]	pop	pop	pop	pop	indie	pop	indie	indie	pop	pop
##	[6171]	indie	metal	metal	pop	pop	indie	indie	pop	metal	pop
##	[6181]	indie	pop	pop	hiphop	hiphop	indie	indie	indie	indie	pop
##	[6191]	pop	indie	indie	pop	pop	hiphop	indie	pop	indie	indie
##	[6201]	pop	indie	pop	pop	pop	pop	indie	hiphop	pop	pop
##	[6211]	metal	indie	pop	pop	pop	indie	pop	pop	indie	pop
##	[6221]	indie	pop	pop	pop	pop	hiphop	pop	hiphop	pop	pop
##	[6231]	pop	indie	hiphop	pop	pop	indie	hiphop	pop	indie	indie
##	[6241]	indie	indie	pop	metal	indie	pop	pop	hiphop	pop	pop
##	[6251]	pop	pop	indie	pop	indie	pop	indie	hiphop	metal	pop
##	[6261]	pop	hiphop	hiphop	pop	hiphop	indie	hiphop	pop	pop	metal
##	[6271]	hiphop	metal	pop	metal	pop	pop	pop	metal	indie	indie
##	[6281]	indie	hiphop	hiphop	indie	indie	pop	pop	metal	indie	pop
##	[6291]	hiphop	pop	indie	indie	pop	metal	metal	pop	indie	indie
##	[6301]	indie	pop	pop	indie	pop	pop	metal	indie	indie	indie
##	[6311]	indie	pop	hiphop	hiphop	indie	hiphop	metal	indie	indie	pop
##	[6321]	metal	pop	pop	indie	metal	pop	indie	pop	pop	pop
##	[6331]	hiphop	hiphop	indie	pop	indie	pop	pop	hiphop	pop	pop
##	[6341]	indie	indie	metal	indie	indie	pop	indie	indie	indie	indie
##	[6351]	indie	indie	indie	pop	pop	pop	pop	hiphop	indie	metal
##	[6361]	pop	pop	pop	metal	hiphop	pop	indie	indie	pop	pop
##	[6371]	hiphop	metal	pop	pop	pop	pop	indie	indie	indie	pop
##	[6381]	indie	indie	pop	indie	pop	indie	pop	indie	hiphop	pop
##	[6391]	indie	indie	pop	metal	hiphop	pop	pop	pop	pop	pop
##	[6401]	pop	pop	pop	pop	pop	hiphop	indie	pop	pop	indie
##	[6411]	indie	pop	indie	pop	hiphop	metal	pop	indie	pop	indie
##	[6421]	pop	indie	indie	pop	indie	indie	indie	pop	hiphop	pop
##	[6431]	pop	pop	metal	indie	hiphop	pop	indie	pop	indie	pop
##	[6441]	pop	indie	pop	pop	hiphop	pop	indie	pop	pop	indie
##	[6451]	pop	indie	pop	indie	indie	pop	indie	metal	indie	indie
##	[6461]	pop	pop	indie	pop	pop	hiphop	pop	metal	pop	pop
##	[6471]	indie	pop	indie	metal	pop	metal	indie	metal	pop	pop
##	[6481]	indie	indie	pop	metal	pop	indie	hiphop	pop	pop	pop
##	[6491]	metal	pop	indie	pop	pop	pop	pop	indie	metal	indie
##	[6501]	pop	metal	pop	pop	pop	pop	hiphop	metal	pop	metal
##	[6511]	indie	pop	hiphop	pop	pop	pop	pop	metal	indie	pop
##	[6521]	indie	pop	pop	hiphop	hiphop	indie	pop	pop	pop	pop
##	[6531]	metal	pop	indie	pop	metal	pop	pop	indie	pop	pop
##	[6541]	indie	pop	pop	pop	indie	indie	indie	pop	hiphop	pop
##	[6551]	indie	pop	indie	pop	indie	indie	pop	hiphop	pop	pop

```
## [6561] metal metal pop pop indie indie indie pop metal pop
## [6571] pop indie hiphop pop pop indie metal indie metal pop
## [6581] pop indie indie pop metal indie pop pop pop pop
## [6591] indie hiphop pop pop indie indie pop indie pop pop
## [6601] pop pop pop pop pop pop hiphop pop indie pop
## [6611] hiphop indie pop indie indie hiphop pop metal pop metal
## [6621] pop indie pop pop pop pop indie pop indie pop
## [6631] pop metal hiphop indie metal indie pop pop pop metal
## [6641] indie metal pop indie hiphop metal metal metal metal indie
## [6651] pop pop pop pop pop indie pop pop indie pop
## [6661] indie pop pop pop pop indie metal pop pop pop
## [6671] pop pop hiphop hiphop pop hiphop pop pop metal metal
## [6681] pop indie indie pop pop metal pop indie indie hiphop
## [6691] hiphop indie indie metal metal indie pop indie indie pop
## [6701] pop indie indie indie pop indie pop indie pop indie
## [6711] indie pop pop pop metal pop pop pop hiphop pop
## [6721] indie indie pop indie indie pop indie pop indie pop
## [6731] pop indie pop indie indie pop pop pop pop indie pop
## [6741] indie metal hiphop pop pop pop pop indie indie indie
## [6751] pop hiphop pop pop indie pop pop pop indie indie
## [6761] indie indie pop indie indie pop metal pop indie pop
## [6771] metal pop pop pop indie indie pop pop pop pop
## [6781] pop pop pop indie hiphop indie pop metal pop indie
## [6791] hiphop pop pop pop indie metal pop pop pop pop
## [6801] pop pop indie metal pop pop hiphop pop indie hiphop
## [6811] pop metal pop indie pop pop pop pop pop pop pop
## [6821] hiphop pop pop indie pop pop pop pop pop pop pop
## [6831] pop pop pop indie indie indie pop pop pop hiphop
## [6841] hiphop pop pop pop metal pop indie pop indie pop
## [6851] indie metal indie indie pop indie indie pop indie metal
## [6861] metal pop pop pop pop hiphop pop indie indie indie
## [6871] pop pop indie indie indie hiphop indie indie pop indie
## [6881] pop metal indie pop pop indie indie pop pop hiphop
## [6891] indie indie pop pop metal metal pop pop
## Levels: hiphop indie metal pop
```

```
summary(knn.pred)
```

```
## hiphop indie metal pop
## 1153 2180 1592 1973
```

```
# how'd we do?
knn_table <- table(knn.pred, test.labels)
knn_table
```

```
## test.labels
```

```
## knn.pred hiphop indie metal pop
## hiphop 772 162 21 198
## indie 176 1035 376 593
## metal 47 432 917 196
## pop 325 581 194 873
```

```
# what's the accuracy?
```

```
mean(knn.pred == test.labels)
```

```
## [1] 0.5214555
```

```
# not too bad!
```

```
# why don't we compare this SAME task to a logistic regression?
```

```
# Multivariate logistic regression
```

```
# and from this package, we're gonna use a fancy new function called "multinom"
multi_class_logit <- multinom(label ~ ., data = spotify, subset = train)
```

```
## # weights: 108 (78 variable)
## initial value 9561.272209
## iter 10 value 8849.927756
## iter 20 value 6417.809934
## iter 30 value 5882.911566
## iter 40 value 5610.726772
## iter 50 value 5524.238960
## iter 60 value 5497.559027
## iter 70 value 5487.786283
## iter 80 value 5486.915196
## final value 5486.901020
## converged
```

```
logit_pred <- predict(multi_class_logit, newdata=spotify[test,], "class")
```

```
# Let's make a table!
```

```
logit_table <- table(spotify$label[test], logit_pred)
logit_table
```

```
##      logit_pred
##      hiphop indie metal pop
## hiphop 902 114 21 283
## indie 135 1197 354 524
## metal 6 238 1222 42
## pop 148 404 50 1258
```



```
# So the logit model is actually much better!  
mean(logit_pred == spotify$label[test])
```

```
## [1] 0.6638156
```