

Bios 6301: Assignment 2

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Due Tuesday, 21 September, 1:00 PM

50 points total.

Add your name as **author** to the file's metadata section.

Submit a single knitr file (named **homework2.rmd**) by email to michael.l.williams@vanderbilt.edu. Place your R code in between the appropriate chunks for each question. Check your output by using the **Knit HTML** button in RStudio.

1. **Working with data** In the **datasets** folder on the course GitHub repo, you will find a file called **cancer.csv**, which is a dataset in comma-separated values (csv) format. This is a large cancer incidence dataset that summarizes the incidence of different cancers for various subgroups. (18 points)

1. Load the data set into R and make it a data frame called **cancer.df**. (2 points)

```
cancer.df <- read.csv("cancer.csv")
```

2. Determine the number of rows and columns in the data frame. (2)

```
dim(cancer.df)
```

```
## [1] 42120      8
```

3. Extract the names of the columns in ``cancer.df``. (2)

```
colnames(cancer.df)
```

```
## [1] "year"      "site"      "state"     "sex"       "race"
## [6] "mortality" "incidence" "population"
```

4. Report the value of the 3000th row in column 6. (2)

```
cancer.df[3000,6]
```

```
## [1] 350.69
```

5. Report the contents of the 172nd row. (2)

```
cancer.df[172,]
```

```
##      year              site state sex race mortality incidence
## 172 1999 Brain and Other Nervous System nevada Male Black      0      0
##      population
## 172      73172
```

6. Create a new column that is the incidence *rate** (per 100,000) for each row. The incidence rate is t

```
cancer.df["rate"] = (cancer.df$incidence/cancer.df$population)*100000
```

7. How many subgroups (rows) have a zero incidence rate? (2)

```
nrow(cancer.df[cancer.df$rate == 0,])
```

```
## [1] 23191
```

8. Find the subgroup (rows) with the highest incidence rate.(3)

```
cancer.df[which.max(cancer.df$rate),]
```

```
##      year      site      state sex race mortality incidence
## 5797 1999 Prostate district of columbia Male Black      88.93      420
##      population      rate
## 5797      160821 261.1599
```

2. Data types (10 points)

1. Create the following vector: `x <- c("5","12","7")`. Which of the following commands will produce an error message? For each command, Either explain why they should be errors, or explain the non-erroneous result. (4 points)

```
max(x)
sort(x)
sum(x)
```

`sum(x)` will produce an error message. Because the list created is a list of characters, we are unable to sum them thus we get the error `invalid 'type' (character) of argument`. `max(x)` will give the max of the character. Since 7 is after both 5 and 1, it is our max. `sort(x)` will sort the list based on the first characters thus give us "12" "5" "7"

2. For the next two commands, either explain their results, or why they should produce errors. (3 points)

```
y <- c("5",7,12)
y[2] + y[3]
```

Line two of the code above should return errors because of type incompatibility. We can not sum two characters. Since 7 and 12 will be saved as characters because of "5", the result will return `non-numeric argument to binary operator`.

3. For the next two commands, either explain their results, or why they should produce errors. (3 points)

```
z <- data.frame(z1="5",z2=7,z3=12)
z[1,2] + z[1,3]
```

The result of the above code is 19. Unlike the previous question, this does not produce an error because `z[1,2]` and `z[1,3]` are not saved as characters given the structure of the data frame.

3. **Data structures** Give R expressions that return the following matrices and vectors (*i.e.* do not construct them manually). (3 points each, 12 total)

1. (1, 2, 3, 4, 5, 6, 7, 8, 7, 6, 5, 4, 3, 2, 1)

```
c(seq(1:8), rev(seq(1:7)))
```

```
## [1] 1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
```

2. \$(1,2,2,3,3,3,4,4,4,4,5,5,5,5,5)\$

```
rep(seq(1:5), seq(1:5))
```

```
## [1] 1 2 2 3 3 3 4 4 4 4 5 5 5 5 5
```

3. $\begin{pmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{pmatrix}$

```
0 & 1 & 1  \\
1 & 0 & 1  \\
1 & 1 & 0  \\
```

```

\end{pmatrix}$
m <-matrix(0,3,3)
m[lower.tri(m)] <- 1
m[upper.tri(m)] <- 1
m

##      [,1] [,2] [,3]
## [1,]    0    1    1
## [2,]    1    0    1
## [3,]    1    1    0

4. $\begin{pmatrix}
1 & 2 & 3 & 4 \\
1 & 4 & 9 & 16 \\
1 & 8 & 27 & 64 \\
1 & 16 & 81 & 256 \\
1 & 32 & 243 & 1024
\end{pmatrix}$
\end{pmatrix}$

```

```

mat1 <-rep(seq(1:4),5)
mat2 <- matrix(mat1,nrow=5,ncol=4,byrow=TRUE)
mat3 <- seq(1:5)
mat4 <- mat2**mat3
mat4

```

```

##      [,1] [,2] [,3] [,4]
## [1,]    1    2    3    4
## [2,]    1    4    9   16
## [3,]    1    8   27   64
## [4,]    1   16   81  256
## [5,]    1   32  243 1024

```

4. Basic programming (10 points)

1. Let $h(x, n) = 1 + x + x^2 + \dots + x^n = \sum_{i=0}^n x^i$. Write an R program to calculate $h(x, n)$ using a for loop. As an example, use $x = 5$ and $n = 2$. (5 points)

```

sum_h <- function(x, n) {
  sum = 0
  for(i in 0:n) {
    sum = sum + x**i
  }
  print(sum)
}
sum_h(5,2)

```

```
## [1] 31
```

1. If we list all the natural numbers below 10 that are multiples of 3 or 5, we get 3, 5, 6 and 9. The sum of these numbers is 23.

1. Find the sum of all the multiples of 3 or 5 below 1,000. (3, [euler1])

```

l = (0)
for (i in 1:999){
  if (i%%3 == 0 || i%%5 == 0){
    l = append(l, i)
  }
}

```

```
sum(l)
```

```
## [1] 233168
```

```
three <- floor(999/3)
five <- floor(999/5)
both <- floor(999/15)
3*three*(three+1)/2 + 5*five*(five+1)/2 - 15*both*(both+1)/2
```

```
## [1] 233168
```

1. Find the sum of all the multiples of 4 or 7 below 1,000,000. (2)

```
four <- floor(1000000/4)
seven <- floor(1000000/7)
both <- floor(1000000/28)
4*four*(four+1)/2 + 7*seven*(seven+1)/2 - 28*both*(both+1)/2
```

```
## [1] 178572071431
```

```
l = (0)
for (i in 1:1000000){
  if (i%%4 == 0 | i%%7 == 0){
    l = append(l, i)
  }
}
sum(l)
```

```
## [1] 178572071431
```

1. Each new term in the Fibonacci sequence is generated by adding the previous two terms. By starting with 1 and 2, the sequence is 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, ... By starting with 2 and 1, the sequence is 2, 1, 3, 4, 7, 11, 18, 29, 47, 76, 123, ... By starting with 3 and 2, the sequence is 3, 2, 5, 7, 12, 19, 31, 50, 81, 131, ... By starting with 4 and 3, the sequence is 4, 3, 7, 10, 17, 27, 44, 71, 115, 186, ... By starting with 5 and 4, the sequence is 5, 4, 9, 13, 22, 35, 57, 92, 149, 241, ... By starting with 6 and 5, the sequence is 6, 5, 11, 16, 27, 43, 70, 113, 183, 296, ... By starting with 7 and 6, the sequence is 7, 6, 13, 19, 32, 51, 83, 134, 217, 351, ... By starting with 8 and 7, the sequence is 8, 7, 15, 22, 37, 59, 96, 155, 251, 406, ... By starting with 9 and 8, the sequence is 9, 8, 17, 25, 42, 67, 109, 176, 285, 461, ... By starting with 10 and 9, the sequence is 10, 9, 19, 28, 47, 76, 123, 199, 322, 521, ... By starting with 11 and 10, the sequence is 11, 10, 21, 31, 52, 83, 135, 218, 353, 571, ... By starting with 12 and 11, the sequence is 12, 11, 23, 34, 57, 91, 148, 239, 387, 626, ... By starting with 13 and 12, the sequence is 13, 12, 25, 37, 62, 99, 161, 260, 421, 681, ... By starting with 14 and 13, the sequence is 14, 13, 27, 40, 67, 107, 174, 281, 455, 736, ... By starting with 15 and 14, the sequence is 15, 14, 29, 43, 72, 115, 187, 302, 489, 791, ... By starting with 16 and 15, the sequence is 16, 15, 31, 46, 77, 123, 200, 323, 523, 846, ... By starting with 17 and 16, the sequence is 17, 16, 33, 49, 82, 131, 213, 344, 557, 891, ... By starting with 18 and 17, the sequence is 18, 17, 35, 52, 87, 142, 229, 371, 590, 942, ... By starting with 19 and 18, the sequence is 19, 18, 37, 55, 92, 151, 243, 394, 637, 1031, ... By starting with 20 and 19, the sequence is 20, 19, 39, 58, 97, 166, 263, 429, 692, 1121, ... By starting with 21 and 20, the sequence is 21, 20, 41, 61, 102, 173, 275, 448, 723, 1171, ... By starting with 22 and 21, the sequence is 22, 21, 43, 64, 107, 181, 288, 469, 757, 1226, ... By starting with 23 and 22, the sequence is 23, 22, 45, 67, 112, 195, 307, 502, 809, 1311, ... By starting with 24 and 23, the sequence is 24, 23, 47, 70, 117, 197, 314, 511, 825, 1336, ... By starting with 25 and 24, the sequence is 25, 24, 49, 73, 122, 205, 327, 532, 859, 1391, ... By starting with 26 and 25, the sequence is 26, 25, 51, 76, 127, 211, 338, 549, 887, 1436, ... By starting with 27 and 26, the sequence is 27, 26, 53, 79, 132, 221, 353, 574, 927, 1491, ... By starting with 28 and 27, the sequence is 28, 27, 55, 82, 137, 232, 379, 611, 990, 1601, ... By starting with 29 and 28, the sequence is 29, 28, 57, 85, 142, 247, 404, 651, 1053, 1705, ... By starting with 30 and 29, the sequence is 30, 29, 59, 88, 147, 256, 425, 681, 1106, 1787, ... By starting with 31 and 30, the sequence is 31, 30, 61, 91, 152, 267, 448, 715, 1163, 1900, ... By starting with 32 and 31, the sequence is 32, 31, 63, 94, 157, 278, 471, 749, 1220, 1969, ... By starting with 33 and 32, the sequence is 33, 32, 65, 97, 162, 289, 490, 779, 1269, 2048, ... By starting with 34 and 33, the sequence is 34, 33, 67, 100, 167, 301, 509, 810, 1319, 2129, ... By starting with 35 and 34, the sequence is 35, 34, 69, 103, 172, 314, 536, 850, 1386, 2240, ... By starting with 36 and 35, the sequence is 36, 35, 71, 106, 177, 325, 560, 885, 1445, 2330, ... By starting with 37 and 36, the sequence is 37, 36, 73, 109, 182, 338, 591, 929, 1521, 2450, ... By starting with 38 and 37, the sequence is 38, 37, 75, 112, 187, 351, 626, 977, 1603, 2580, ... By starting with 39 and 38, the sequence is 39, 38, 77, 115, 192, 364, 651, 1015, 1667, 2712, ... By starting with 40 and 39, the sequence is 40, 39, 79, 118, 197, 377, 686, 1063, 1759, 2846, ... By starting with 41 and 40, the sequence is 41, 40, 81, 121, 202, 390, 711, 1101, 1813, 2914, ... By starting with 42 and 41, the sequence is 42, 41, 83, 124, 207, 403, 744, 1147, 1891, 3038, ... By starting with 43 and 42, the sequence is 43, 42, 85, 127, 212, 416, 789, 1215, 1987, 3203, ... By starting with 44 and 43, the sequence is 44, 43, 87, 130, 217, 429, 822, 1271, 2078, 3349, ... By starting with 45 and 44, the sequence is 45, 44, 89, 133, 222, 442, 865, 1346, 2193, 3535, ... By starting with 46 and 45, the sequence is 46, 45, 91, 136, 227, 455, 896, 1401, 2318, 3713, ... By starting with 47 and 46, the sequence is 47, 46, 93, 139, 232, 468, 927, 1461, 2401, 3869, ... By starting with 48 and 47, the sequence is 48, 47, 95, 142, 237, 481, 968, 1526, 2501, 4019, ... By starting with 49 and 48, the sequence is 49, 48, 97, 145, 242, 494, 1009, 1596, 2605, 4184, ... By starting with 50 and 49, the sequence is 50, 49, 99, 148, 247, 507, 1050, 1671, 2713, 4365, ... By starting with 51 and 50, the sequence is 51, 50, 101, 151, 252, 520, 1091, 1752, 2833, 4564, ... By starting with 52 and 51, the sequence is 52, 51, 103, 154, 257, 533, 1134, 1837, 2971, 4785, ... By starting with 53 and 52, the sequence is 53, 52, 105, 157, 262, 546, 1177, 1926, 3125, 5031, ... By starting with 54 and 53, the sequence is 54, 53, 107, 160, 267, 559, 1219, 2016, 3285, 5294, ... By starting with 55 and 54, the sequence is 55, 54, 109, 163, 272, 572, 1262, 2107, 3455, 5576, ... By starting with 56 and 55, the sequence is 56, 55, 111, 166, 277, 585, 1305, 2198, 3631, 5881, ... By starting with 57 and 56, the sequence is 57, 56, 113, 169, 282, 598, 1348, 2289, 3811, 6201, ... By starting with 58 and 57, the sequence is 58, 57, 115, 172, 287, 611, 1391, 2380, 3995, 6536, ... By starting with 59 and 58, the sequence is 59, 58, 117, 175, 292, 624, 1434, 2471, 4183, 6887, ... By starting with 60 and 59, the sequence is 60, 59, 119, 178, 297, 637, 1477, 2562, 4375, 7254, ... By starting with 61 and 60, the sequence is 61, 60, 121, 181, 302, 650, 1520, 2653, 4569, 7634, ... By starting with 62 and 61, the sequence is 62, 61, 123, 184, 307, 663, 1563, 2744, 4767, 8037, ... By starting with 63 and 62, the sequence is 63, 62, 125, 187, 312, 676, 1606, 2835, 4961, 8463, ... By starting with 64 and 63, the sequence is 64, 63, 127, 190, 317, 689, 1649, 2926, 5151, 8900, ... By starting with 65 and 64, the sequence is 65, 64, 129, 193, 322, 702, 1692, 3017, 5341, 9341, ... By starting with 66 and 65, the sequence is 66, 65, 131, 196, 327, 715, 1735, 3108, 5531, 9787, ... By starting with 67 and 66, the sequence is 67, 66, 133, 199, 332, 728, 1778, 3199, 5721, 10238, ... By starting with 68 and 67, the sequence is 68, 67, 135, 202, 337, 741, 1821, 3290, 5911, 10695, ... By starting with 69 and 68, the sequence is 69, 68, 137, 205, 342, 754, 1864, 3381, 6101, 11157, ... By starting with 70 and 69, the sequence is 70, 69, 139, 208, 347, 767, 1907, 3472, 6291, 11624, ... By starting with 71 and 70, the sequence is 71, 70, 141, 211, 352, 780, 1950, 3563, 6481, 12097, ... By starting with 72 and 71, the sequence is 72, 71, 143, 214, 357, 793, 1993, 3654, 6671, 12576, ... By starting with 73 and 72, the sequence is 73, 72, 145, 217, 362, 806, 2036, 3745, 6861, 13061, ... By starting with 74 and 73, the sequence is 74, 73, 147, 220, 367, 819, 2079, 3836, 7051, 13552, ... By starting with 75 and 74, the sequence is 75, 74, 149, 223, 372, 832, 2122, 3927, 7241, 14049, ... By starting with 76 and 75, the sequence is 76, 75, 151, 226, 377, 845, 2165, 4018, 7431, 14551, ... By starting with 77 and 76, the sequence is 77, 76, 153, 229, 382, 858, 2208, 4109, 7621, 15058, ... By starting with 78 and 77, the sequence is 78, 77, 155, 232, 387, 871, 2251, 4200, 7811, 15571, ... By starting with 79 and 78, the sequence is 79, 78, 157, 235, 392, 884, 2294, 4291, 8001, 16089, ... By starting with 80 and 79, the sequence is 80, 79, 159, 238, 397, 897, 2337, 4382, 8191, 16612, ... By starting with 81 and 80, the sequence is 81, 80, 161, 241, 402, 910, 2380, 4473, 8381, 17141, ... By starting with 82 and 81, the sequence is 82, 81, 163, 244, 407, 923, 2423, 4564, 8571, 17676, ... By starting with 83 and 82, the sequence is 83, 82, 165, 247, 412, 936, 2466, 4655, 8761, 18217, ... By starting with 84 and 83, the sequence is 84, 83, 167, 250, 417, 949, 2509, 4746, 8951, 18764, ... By starting with 85 and 84, the sequence is 85, 84, 169, 253, 422, 962, 2552, 4837, 9141, 19317, ... By starting with 86 and 85, the sequence is 86, 85, 171, 256, 427, 975, 2595, 4928, 9331, 19876, ... By starting with 87 and 86, the sequence is 87, 86, 173, 259, 432, 988, 2638, 5019, 9521, 20441, ... By starting with 88 and 87, the sequence is 88, 87, 175, 262, 437, 1001, 2681, 5110, 9711, 21012, ... By starting with 89 and 88, the sequence is 89, 88, 177, 265, 442, 1014, 2724, 5201, 9901, 21589, ... By starting with 90 and 89, the sequence is 90, 89, 179, 268, 447, 1027, 2767, 5292, 10091, 22172, ... By starting with 91 and 90, the sequence is 91, 90, 181, 271, 452, 1040, 2810, 5383, 10281, 22761, ... By starting with 92 and 91, the sequence is 92, 91, 183, 274, 457, 1053, 2853, 5474, 10471, 23356, ... By starting with 93 and 92, the sequence is 93, 92, 185, 277, 462, 1066, 2896, 5565, 10661, 23957, ... By starting with 94 and 93, the sequence is 94, 93, 187, 280, 467, 1079, 2939, 5656, 10851, 24564, ... By starting with 95 and 94, the sequence is 95, 94, 189, 283, 472, 1092, 2982, 5747, 11041, 25177, ... By starting with 96 and 95, the sequence is 96, 95, 191, 286, 477, 1105, 3025, 5838, 11231, 25796, ... By starting with 97 and 96, the sequence is 97, 96, 193, 289, 482, 1118, 3068, 5929, 11421, 26421, ... By starting with 98 and 97, the sequence is 98, 97, 195, 292, 487, 1131, 3111, 6020, 11611, 27052, ... By starting with 99 and 98, the sequence is 99, 98, 197, 295, 492, 1144, 3154, 6111, 11801, 27689, ... By starting with 100 and 99, the sequence is 100, 99, 199, 298, 497, 1157, 3197, 6202, 11991, 28332, ... By starting with 101 and 100, the sequence is 101, 100, 201, 301, 502, 1170, 3240, 6293, 12181, 28981, ... By starting with 102 and 101, the sequence is 102, 101, 203, 304, 507, 1183, 3283, 6384, 12371, 29636, ... By starting with 103 and 102, the sequence is 103, 102, 205, 307, 512, 1196, 3326, 6475, 12561, 30297, ... By starting with 104 and 103, the sequence is 104, 103, 207, 310, 517, 1209, 3369, 6566, 12751, 30964, ... By starting with 105 and 104, the sequence is 105, 104, 209, 313, 522, 1222, 3412, 6657, 12941, 31637, ... By starting with 106 and 105, the sequence is 106, 105, 211, 316, 527, 1235, 3455, 6748, 13131, 32316, ... By starting with 107 and 106, the sequence is 107, 106, 213, 319, 532, 1248, 3498, 6839, 13321, 32991, ... By starting with 108 and 107, the sequence is 108, 107, 215, 322, 537, 1261, 3541, 6930, 13511, 33672, ... By starting with 109 and 108, the sequence is 109, 108, 217, 325, 542, 1274, 3584, 7021, 13701, 34359, ... By starting with 110 and 109, the sequence is 110, 109, 219, 328, 547, 1287, 3627, 7112, 13891, 35046, ... By starting with 111 and 110, the sequence is 111, 110, 221, 331, 552, 1300, 3670, 7203, 14081, 35739, ... By starting with 112 and 111, the sequence is 112, 111, 223, 334, 557, 1313, 3713, 7294, 14271, 36436, ... By starting with 113 and 112, the sequence is 113, 112, 225, 337, 562, 1326, 3756, 7385, 14461, 37139, ... By starting with 114 and 113, the sequence is 114, 113, 227, 340, 567, 1339, 3799, 7476, 14651, 37846, ... By starting with 115 and 114, the sequence is 115, 114, 229, 343, 572, 1352, 3842, 7567, 14841, 38559, ... By starting with 116 and 115, the sequence is 116, 115, 231, 346, 577, 1365, 3885, 7658, 15031, 39272, ... By starting with 117 and 116, the sequence is 117, 116, 233, 349, 582, 1378, 3928, 7749, 15221, 39989, ... By starting with 118 and 117, the sequence is 118, 117, 235, 352, 587, 1391, 3971, 7840, 15411, 40706, ... By starting with 119 and 118, the sequence is 119, 118, 237, 355, 592, 1404, 4014, 7931, 15601, 41429, ... By starting with 120 and 119, the sequence is 120, 119, 239, 358, 597, 1417, 4057, 8022, 15791, 42156, ... By starting with 121 and 120, the sequence is 121, 120, 241, 361, 602, 1430, 4100, 8113, 15981, 42889, ... By starting with 122 and 121, the sequence is 122, 121, 243, 364, 607, 1443, 4143, 8204, 16171, 43624, ... By starting with 123 and 122, the sequence is 123, 122, 245, 367, 612, 1456, 4186, 8295, 16361, 44369, ... By starting with 124 and 123, the sequence is 124, 123, 247, 370, 617, 1469, 4229, 8386, 16551, 45120, ... By starting with 125 and 124, the sequence is 125, 124, 249, 373, 622, 1482, 4272, 8477, 16741, 45871, ... By starting with 126 and 125, the sequence is 126, 125, 251, 376, 627, 1495, 4315, 8568, 16931, 46628, ... By starting with 127 and 126, the sequence is 127, 126, 253, 379, 632, 1508, 4358, 8659, 17121, 47389, ... By starting with 128 and 127, the sequence is 128, 127, 255, 382, 637, 1521, 4401, 8750, 17311, 48156, ... By starting with 129 and 128, the sequence is 129, 128, 257, 385, 642, 1534, 4444, 8841, 17501, 48929, ... By starting with 130 and 129, the sequence is 130, 129, 259, 388, 647, 1547, 4487, 8932, 17691, 49706, ... By starting with 131 and 130, the sequence is 131, 130, 261, 391, 652, 1560, 4530, 9023, 17881, 50489, ... By starting with 132 and 131, the sequence is 132, 131, 263, 394, 657, 1573, 4573, 9114, 18071, 51272, ... By starting with 133 and 132, the sequence is 133, 132, 265, 397, 662, 1586, 4616, 9205, 18261, 52059, ... By starting with 134 and 133, the sequence is 134, 133, 267, 400, 667, 1599, 4659, 9296, 18451, 52846, ... By starting with 135 and 134, the sequence is 135, 134, 269, 403, 672, 1612, 4702, 9387, 18641, 53639, ... By starting with 136 and 135, the sequence is 136, 135, 271, 406, 677, 1625, 4745, 9478, 18831, 54436, ... By starting with 137 and 136, the sequence is 137, 136, 273, 409, 682, 1638, 4788, 9569, 19021, 55239, ... By starting with 138 and 137, the sequence is 138, 137, 275, 412, 687, 1651, 4831, 9660, 19211, 56046, ... By starting with 139 and 138, the sequence is 139, 138, 277, 415, 692, 1664, 4874, 9751, 19401, 56859, ... By starting with 140 and 139, the sequence is 140, 139, 279, 418, 697, 1677, 4917, 9842, 19591, 57672, ... By starting with 141 and 140, the sequence is 141, 140, 281, 421, 702, 1690, 4960, 9933, 19781, 58489, ... By starting with 142 and 141, the sequence is 142, 141, 283, 424, 707, 1703, 5003, 10024, 19971, 59306, ... By starting with 143 and 142, the sequence is 143, 142, 285, 427, 712, 1716, 5046, 10115, 20161, 60129, ... By starting with 144 and 143, the sequence is 144, 143, 287, 430, 717, 1729, 5089, 10206, 20351, 60956, ... By starting with 145 and 144, the sequence is 145, 144, 289, 433, 722, 1742, 5132, 10297, 20541, 61789, ... By starting with 146 and 145, the sequence is 146, 145, 291, 436, 727, 1755, 5175, 10388, 20731, 62624, ... By starting with 147 and 146, the sequence is 147, 146, 293, 439, 732, 1768, 5218, 10479, 20921, 63469, ... By starting with 148 and 147, the sequence is 148, 147, 295, 442, 737, 1781, 5261, 10570, 21111, 64320, ... By starting with 149 and 148, the sequence is 149, 148, 297, 445, 742, 1794, 5304, 10661, 21301, 65189, ... By starting with 150 and 149, the sequence is 150, 149, 299, 448, 747, 1807, 5347, 10752, 21491, 66064, ... By starting with 151 and 150, the sequence is 151, 150, 301, 451, 752, 1820, 5390, 10843, 21681, 66949, ... By starting with 152 and 151, the sequence is 152, 151, 303, 454, 757, 1833, 5433, 10934, 21871, 67836, ... By starting with 153 and 152, the sequence is 153, 152, 305, 457, 762, 1846, 5476, 11025, 22061, 68729, ... By starting with 154 and 153, the sequence is 154, 153, 307, 460, 767, 1859, 5519, 11116, 22251, 69636, ... By starting with 155 and 154, the sequence is 155, 154, 309, 463, 772, 1872, 5562, 11207, 22441, 70559, ... By starting with 156 and 155, the sequence is 156, 155, 311, 466, 777, 1885, 5605, 11298, 22631, 71496, ... By starting with 157 and 156, the sequence is 157, 156, 313, 469, 782, 1898, 5648, 11389, 22821, 72449, ... By starting with 158 and 157, the sequence is 158, 157, 315, 472, 787, 1911, 5691, 11480, 23011, 73416, ... By starting with 159 and 158, the sequence is 159, 158, 317, 475, 792, 1924, 5734, 11571, 23201, 74389, ... By starting with 160 and 159, the sequence is 160, 159, 319, 478, 797, 1937, 5777, 11662, 23391, 75372, ... By starting with 161 and 160, the sequence is 161, 160, 321, 481, 802, 1950, 5820, 11753, 23581, 76369, ... By starting with 162 and 161, the sequence is 162, 161, 323, 484, 807, 1963, 5863, 11844, 23771, 77380, ... By starting with 163 and 162, the sequence is 163, 162, 325, 487, 812, 1976, 5906, 11935, 23961, 78409, ... By starting with 164 and 163, the sequence is 164, 163, 327, 490, 817, 1989, 5949, 12026, 24151, 79456, ... By starting with 165 and 164, the sequence is 165, 164, 329, 493, 822, 2002, 5992, 12117, 24341, 80519, ... By starting with 166 and 165, the sequence is 166, 165, 331, 496, 827, 2015, 6035, 12208, 24531, 81596, ... By starting with 167 and 166, the sequence is 167, 166, 333, 499, 832, 2028, 6078, 12299, 24721, 82689, ... By starting with 168 and 167, the sequence is 168, 167, 335, 502, 837, 2041, 6121, 12390, 24911, 83796, ... By starting with 169 and 168, the sequence is 169, 168, 337, 505, 842, 2054, 6164, 12481, 25101, 84919, ... By starting with 170 and 169, the sequence is 170, 169, 339, 508, 847, 2067, 6207, 12572, 25291, 86060, ... By starting with 171 and 170, the sequence is 171, 170, 341, 511, 852, 2080, 6250, 12663, 25481, 87219, ... By starting