

Class 9: Structural Bioinformatics pt. 1

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The main repository for biomolecular structure data is the Protein Data Bank (PDB)
<https://www.rcsb.org>

Let's have a quick look at the composition of this database:

```
stats <- read.csv("Data Export Summary.csv")
head(stats)
```

	Molecular.Type	X.ray	EM	NMR	Integrative	Multiple.methods
1	Protein (only)	176,378	20,438	12,709	342	221
2	Protein/Oligosaccharide	10,284	3,396	34	8	11
3	Protein/NA	9,007	5,931	287	24	7
4	Nucleic acid (only)	3,077	200	1,554	2	15
5	Other	174	13	33	3	0
6	Oligosaccharide (only)	11	0	6	0	1
	Neutron Other Total					
1	83 32	210,203				
2	1 0	13,734				
3	0 0	15,256				
4	3 1	4,852				
5	0 0	223				
6	0 4	22				

Q1: What percentage of structures in the PDB are solved by X-Ray and Electron Microscopy.

```
#first convert characters to integers
as.numeric(sub(",", "", stats$X.ray))
```

```
[1] 176378 10284 9007 3077 174 11
```

This is annoying let's try a different import function from the **readr** package.

```
library(readr)

stats <- read_csv("Data Export Summary.csv")
```

```
Rows: 6 Columns: 9
-- Column specification -----
Delimiter: ","
chr (1): Molecular Type
dbl (4): Integrative, Multiple methods, Neutron, Other
num (4): X-ray, EM, NMR, Total

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.
```

If you don't want to load the whole package, you can use `readr::read_csv()`

```
#percent X-ray
n.total <- sum(stats$Total)
n.xray <- sum(stats$`X-ray`)

round(n.xray/n.total * 100, 2)
```

```
[1] 81.43
```

```
#percent EM
n.EM <- sum(stats$EM)

round(n.EM/n.total * 100, 2)
```

```
[1] 12.27
```

Q2: What proportion of structures in the PDB are protein only?

```
n.protein <- stats[1, "Total"]

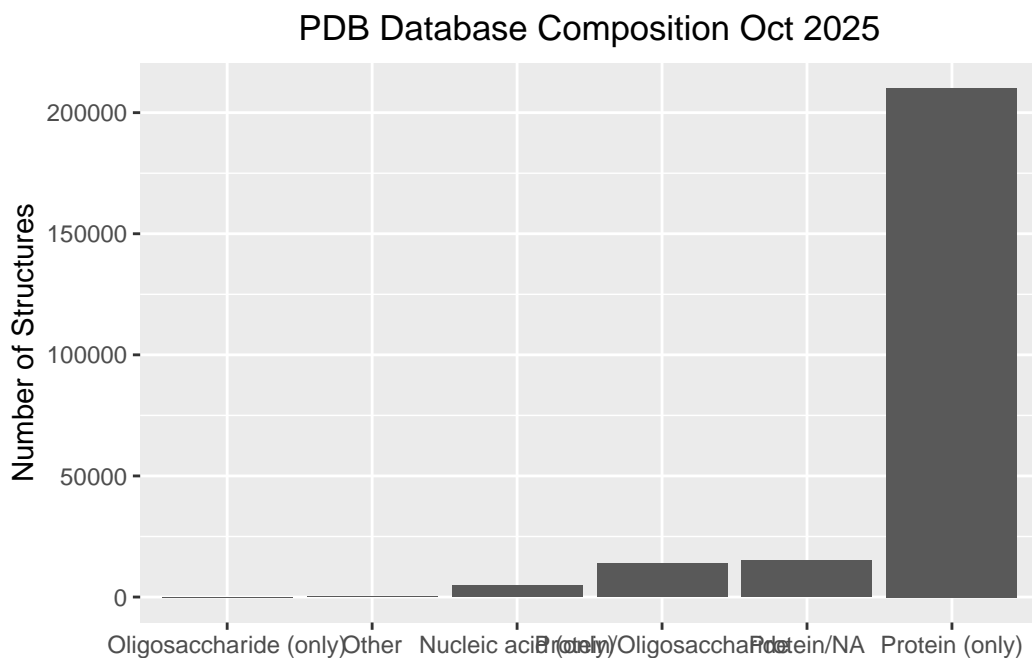
round(n.protein/n.total *100, 2)
```

```
Total
1 86.05
```

Q3. Make a bar plot overview of Molecular type composition using ggplot

```
library(ggplot2)

ggplot(stats)+
  aes(reorder(`Molecular Type`, Total), Total)+
  geom_col()+
  labs(title="PDB Database Composition Oct 2025") +
  theme(plot.title = element_text(hjust=0.5)) +
  xlab(NULL) +
  ylab("Number of Structures")
```



visualizing structure data

The Mol* viewer is embedded in many bioinformatics websites. The homepage is <https://molstar.org>

I can insert any figure or image file using markdown format



Figure 1: The HIV-Pr dimer with bound inhibitor

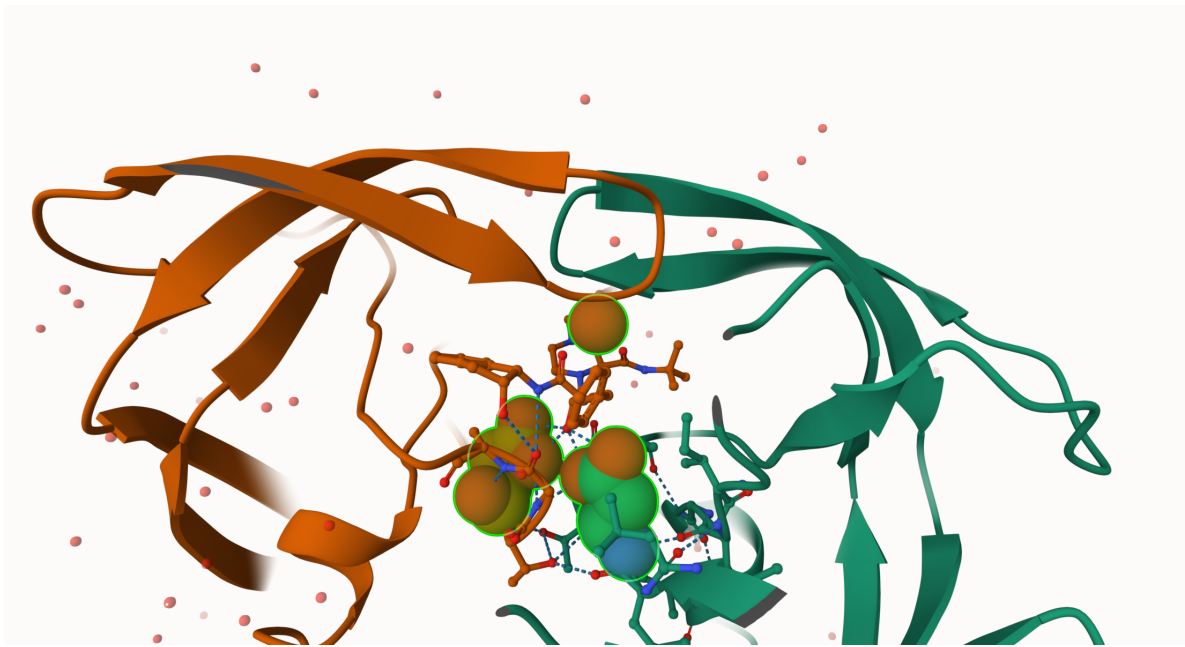


Figure 2: catalytic binding site with Asp and a water molecule

Bio3D package for structural bioinformatics

We can use the bio3d package to read and analyze biomolecular data in R:

```
library(bio3d)
```

```
hiv <- read.pdb("1hsg")
```

Note: Accessing on-line PDB file

```
hiv
```

```
Call: read.pdb(file = "1hsg")
```

```
Total Models#: 1
```

```
Total Atoms#: 1686, XYZs#: 5058 Chains#: 2 (values: A B)
```

```
Protein Atoms#: 1514 (residues/Calpha atoms#: 198)
```

```
Nucleic acid Atoms#: 0 (residues/phosphate atoms#: 0)
```

Non-protein/nucleic Atoms#: 172 (residues: 128)
 Non-protein/nucleic resid values: [HOH (127), MK1 (1)]

Protein sequence:

PQITLWQRPLVTIKIGGQLKEALLDTGADDTVLEEMSLPGRWKPKMIGGIGGFIKVRQYD
 QILIEICGHKAIGTVLVGPTPVNIIGRNLLTQIGCTLNFPQITLWQRPLVTIKIGGQLKE
 ALLDTGADDTVLEEMSLPGRWKPKMIGGIGGFIKVRQYDQILIEICGHKAIGTVLVGPTP
 VNIIGRNLLTQIGCTLNF

+ attr: atom, xyz, seqres, helix, sheet,
 calpha, remark, call

`head(hiv$atom)`

	type	eleno	elety	alt	resid	chain	resno	insert	x	y	z	o	b
1	ATOM	1	N	<NA>	PRO	A	1	<NA>	29.361	39.686	5.862	1	38.10
2	ATOM	2	CA	<NA>	PRO	A	1	<NA>	30.307	38.663	5.319	1	40.62
3	ATOM	3	C	<NA>	PRO	A	1	<NA>	29.760	38.071	4.022	1	42.64
4	ATOM	4	O	<NA>	PRO	A	1	<NA>	28.600	38.302	3.676	1	43.40
5	ATOM	5	CB	<NA>	PRO	A	1	<NA>	30.508	37.541	6.342	1	37.87
6	ATOM	6	CG	<NA>	PRO	A	1	<NA>	29.296	37.591	7.162	1	38.40
	segid	elasy	charge										
1	<NA>	N	<NA>										
2	<NA>	C	<NA>										
3	<NA>	C	<NA>										
4	<NA>	O	<NA>										
5	<NA>	C	<NA>										
6	<NA>	C	<NA>										

Let's get the sequence:

`pdbseq(hiv)`

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
"P"	"Q"	"I"	"T"	"L"	"W"	"Q"	"R"	"P"	"L"	"V"	"T"	"I"	"K"	"I"	"G"	"G"	"Q"	"L"	"K"
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
"E"	"A"	"L"	"L"	"D"	"T"	"G"	"A"	"D"	"D"	"T"	"V"	"L"	"E"	"E"	"M"	"S"	"L"	"P"	"G"
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
"R"	"W"	"K"	"P"	"K"	"M"	"I"	"G"	"G"	"I"	"G"	"G"	"F"	"I"	"K"	"V"	"R"	"Q"	"Y"	"D"
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

```

"Q" "I" "L" "I" "E" "I" "C" "G" "H" "K" "A" "I" "G" "T" "V" "L" "V" "G" "P" "T"
81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 1
"P" "V" "N" "I" "I" "G" "R" "N" "L" "L" "T" "Q" "I" "G" "C" "T" "L" "N" "F" "P"
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
"Q" "I" "T" "L" "W" "Q" "R" "P" "L" "V" "T" "I" "K" "I" "G" "G" "Q" "L" "K" "E"
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41
"A" "L" "L" "D" "T" "G" "A" "D" "D" "T" "V" "L" "E" "E" "M" "S" "L" "P" "G" "R"
42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61
"W" "K" "P" "K" "M" "I" "G" "G" "I" "G" "G" "F" "I" "K" "V" "R" "Q" "Y" "D" "Q"
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81
"I" "L" "I" "E" "I" "C" "G" "H" "K" "A" "I" "G" "T" "V" "L" "V" "G" "P" "T" "P"
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
"V" "N" "I" "I" "G" "R" "N" "L" "L" "T" "Q" "I" "G" "C" "T" "L" "N" "F"

```

Let's trim to Chain A and get just its sequence:

```

chainA <- trim.pdb(hiv, chain="A")
chainA.seq <- pdbseq(chainA)

```

Let's blast:

```

blast <- blast.pdb(chainA.seq)

```

Searching ... please wait (updates every 5 seconds) RID = G5B9B48X014

.

Reporting 249 hits

```

head(blast$hit.tbl)

```

	queryid	subjectids	identity	alignmentlength	mismatches	gapopens	q.start		
1	Query_4940319	1W5V_A	100.00	99	0	0	1		
2	Query_4940319	2FDE_A	100.00	99	0	0	1		
3	Query_4940319	1AJV_A	100.00	99	0	0	1		
4	Query_4940319	2R38_A	98.99	99	1	0	1		
5	Query_4940319	2R3T_A	98.99	99	1	0	1		
6	Query_4940319	1HXB_A	98.99	99	1	0	1		
	q.end	s.start	s.end	eval	bitscore	positives	mlog.eval	pdb.id	acc
1	99	12	110	1.38e-67	199	100	153.9511	1W5V_A	1W5V_A
2	99	2	100	1.70e-67	198	100	153.7426	2FDE_A	2FDE_A
3	99	1	99	1.99e-67	198	100	153.5851	1AJV_A	1AJV_A

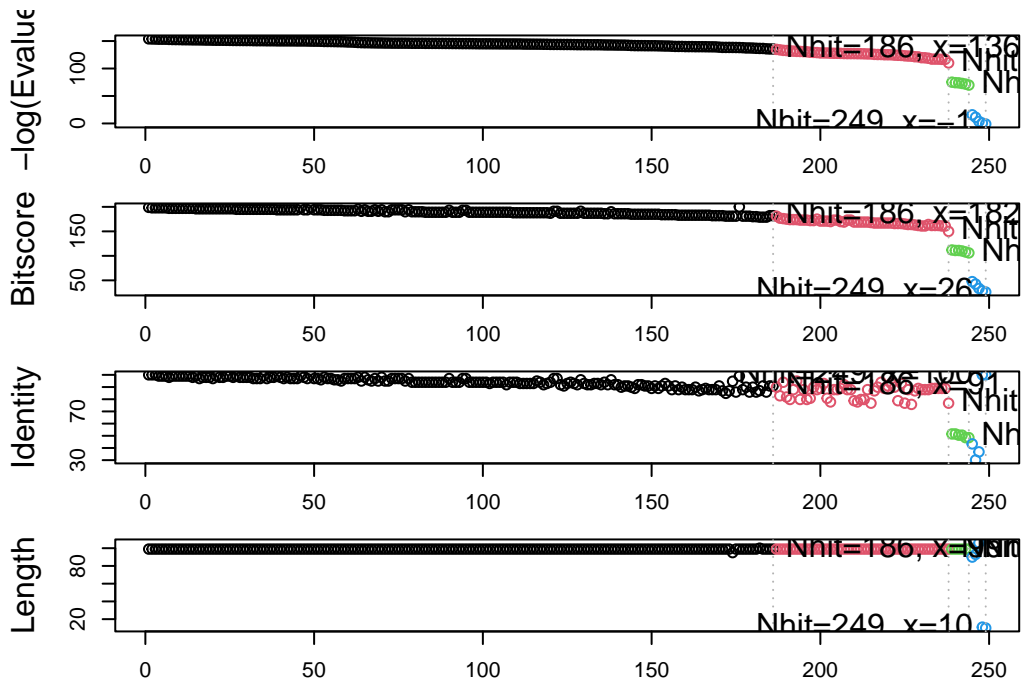
4	99	1	99	2.50e-67	198	100	153.3569	2R38_A	2R38_A
5	99	1	99	2.50e-67	198	100	153.3569	2R3T_A	2R3T_A
6	99	1	99	2.50e-67	198	100	153.3569	1HXB_A	1HXB_A

Plot a quick overview of blast results

```
hits <- plot(blast)
```

```
* Possible cutoff values: 135 110 69 -2
    Yielding Nhits: 186 238 244 249
```

```
* Chosen cutoff value of: 69
    Yielding Nhits: 244
```



```
#just the accession numbers of the hits we got
hits$ pdb.id
```

```
[1] "1W5V_A" "2FDE_A" "1AJV_A" "2R38_A" "2R3T_A" "1HXB_A" "1BV9_A" "1AAQ_A"
[9] "1AXA_A" "1HVS_A" "1ZP8_A" "2QHC_A" "1A8G_A" "204L_A" "5COK_A" "1TCX_A"
[17] "2Z54_A" "1D4S_A" "1BV7_A" "1BWA_A" "1A9M_A" "2FLE_A" "1ODY_A" "1GNN_A"
[25] "1GNM_A" "5YRS_B" "1HEF_E" "1ODX_A" "4QGI_A" "1BVE_A" "2AZ8_A" "1A30_A"
```



```

[33] "6DH6_A" "6DH0_A" "2I4D_A" "600S_A" "1RL8_A" "5YRS_A" "1ZSF_A" "2Q64_A"
[41] "6DH3_A" "2NPH_A" "2Q63_A" "1LZQ_A" "1FB7_A" "1G6L_A" "1HIV_A" "600U_A"
[49] "1HVC_A" "2I4V_A" "2AZ9_A" "600T_A" "2P3B_B" "5KAO_A" "2WLO_A" "60PT_A"
[57] "1IZI_A" "1MRX_A" "2PYM_A" "2PYN_A" "1DMP_A" "4K4P_A" "1LV1_A" "1AID_A"
[65] "1LV1_A" "1ZBG_A" "3TKG_A" "1HVC_A" "5YOK_A" "1G6L_A" "1FGC_C" "3K4V_A"
[73] "3KT5_A" "3KT5_A" "4QLH_A" "4QLH_A" "2F3K_A" "4Q5M_A" "2AOC_A" "3B80_A"
[81] "3VF5_A" "2AVQ_A" "1DW6_C" "1KZK_A" "2HS1_A" "1K6C_A" "1MTB_A" "4Q1X_A"
[89] "4Q1W_A" "4Q5M_A" "3D1X_A" "2AVM_A" "3PWM_A" "3KT2_A" "3KT2_A" "1SDV_A"
[97] "3JVV_A" "3OY4_A" "1A94_A" "2HS2_A" "4EJ8_A" "2FGU_A" "2AVV_A" "3JW2_A"
[105] "3BVA_A" "1FFF_C" "3S43_B" "2NXD_A" "1FG6_C" "1EBK_C" "4Q1Y_A" "3EL4_A"
[113] "1F7A_A" "1K2B_A" "2FGV_A" "1Z8C_A" "2G69_A" "3EL9_A" "3OXV_A" "1BDR_A"
[121] "3N3I_A" "3N3I_A" "3OXW_A" "3S43_A" "3EM3_A" "3CYW_A" "5KQX_A" "2B60_A"
[129] "7DOZ_A" "1K2C_A" "1MT7_A" "3EM4_A" "4QJ9_A" "1BDL_A" "3LZS_A" "5T84_A"
[137] "4DQB_A" "7DOZ_A" "4QJ2_A" "3LZV_A" "1SGU_A" "2FXE_A" "1BDQ_A" "3U71_A"
[145] "2R5P_A" "40BD_A" "7MAS_A" "3IX0_A" "3D3T_A" "5YOJ_A" "3LZU_A" "4NJS_A"
[153] "3EKP_A" "1B6J_A" "3EKQ_A" "2RKF_A" "1C6X_A" "7MAR_A" "4DQF_A" "1RPI_A"
[161] "3OU1_B" "3PJ6_A" "2P3A_A" "60GQ_A" "3OQ7_A" "5KR1_A" "3OQD_A" "4RVI_A"
[169] "3OQA_A" "1B6K_A" "3OUD_B" "6MK9_A" "3S09_A" "1Q9P_A" "6I45_A" "7SEP_A"
[177] "4NJT_A" "3BXR_A" "4YOA_A" "4DQC_A" "2FDD_A" "2RKG_A" "4DQH_A" "2P3C_A"
[185] "4EP2_A" "4EP2_A" "4EQ0_A" "4NPT_A" "60PU_A" "4NPU_A" "3U7S_A" "3HAW_A"
[193] "2AZB_A" "3TTP_A" "3HBO_A" "3GGU_A" "7N6T_A" "60PV_A" "4EQ0_A" "60PX_A"
[201] "2O4N_A" "5T2E_A" "3UCB_A" "3KA2_A" "3FSM_A" "60PW_A" "2AZC_A" "3FSM_A"
[209] "3HLO_A" "2P3D_A" "3T3C_A" "7MYP_A" "6054_X" "60PY_A" "4Z4X_A" "60PZ_A"
[217] "2JE4_A" "1DAZ_C" "7MAP_A" "7MAQ_A" "1K1U_A" "2B7Z_A" "3MWS_A" "1K1T_A"
[225] "8DCH_A" "3I2L_A" "6P9A_A" "2FXD_A" "2J9J_A" "3DCK_A" "2J9J_B" "3NXE_A"
[233] "2O4O_A" "2O4O_A" "3NXE_A" "3KA2_A" "3HLO_A" "5B18_A" "1SIP_A" "2SAM_A"
[241] "1AZ5_A" "1SIV_A" "1HII_A" "1IVP_A"

```

Prediction of functional motions

We can run a Normal Mode Analysis (NMA) to predict large scale motions/flexibility/dynamics of any biomolecule that we can read into R.

Let's look at ADK and chain A only:

```
adk <- read.pdb("1ake")
```

Note: Accessing on-line PDB file

PDB has ALT records, taking A only, rm.alt=TRUE

```
adk_A <- trim.pdb(adk, chain="A")
adk_A
```

Call: trim.pdb(pdb = adk, chain = "A")

Total Models#: 1

Total Atoms#: 1954, XYZs#: 5862 Chains#: 1 (values: A)

Protein Atoms#: 1656 (residues/Calpha atoms#: 214)

Nucleic acid Atoms#: 0 (residues/phosphate atoms#: 0)

Non-protein/nucleic Atoms#: 298 (residues: 242)

Non-protein/nucleic resid values: [AP5 (1), HOH (241)]

Protein sequence:

```
MRIILLGAPGAGKGTQAQFIMEKYGIPQISTGDMRLRAAVKSGSELGKQAKDIMDAGKLV
TDELVIALVKERIAQEDCRNGFLDGFPR TIPQADAMKEAGINVDYVLEFDVPDELIVDRI
VGRRVHAPSGRVYHV KFNPPKVEGKDDVTGEELTTRKDDQEETVRKRLVEYHQMTAPLIG
YYSKEAEAGNTKYAKVDGTPVAEVRADLEKILG
```

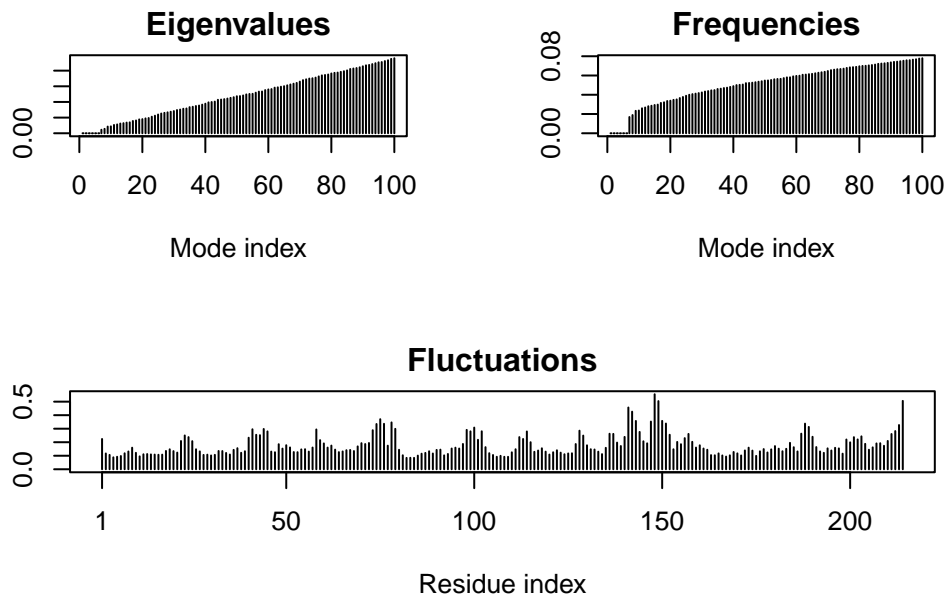
+ attr: atom, helix, sheet, seqres, xyz,
calpha, call

```
m <- nma(adk_A)
```

Building Hessian... Done in 0.05 seconds.

Diagonalizing Hessian... Done in 0.24 seconds.

```
plot(m)
```



Let's write out a "trajectory" of predicted motion

```
#also saving trajectory as a file  
mktrj(m, file="adk_nma.pdb")
```

Play with 3D viewing in R

We can use the new **bio3dview** package, which is not yet on CRAN, to render interactive 3D views in R and HTML quarto output reports.

To install from Github, we can use the **pak** package.