2017

CURRICULUM VITAE

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Academic Appointments and Education:

1970:	B.S. in Chemistry, Moscow University, Moscow, Russia.
1973:	Ph.D. in Biochemistry, Institute of Molecular Biology, Moscow.
1973-1976:	Research Fellow, Institute of Molecular Biology, Moscow.
1977-1980:	Assistant Professor, Dept. of Biology, M. I. T., Cambridge, MA.
1980-1986:	Associate Professor, Department of Biology, M. I. T.
1986-1992:	Professor of Biology, Department of Biology, M. I. T.
1992-2017:	Howard and Gwen Lawry Smits Professor of Cell Biology, Division of Biology, California Institute of Technology, Pasadena, CA.
2017-present:	Thomas Hunt Morgan Professor of Biology, Division of Biology and Biological Engineering, California Institute of Technology, Pasadena, CA.

Other Appointments:
Member, Molecular Cytology Study Section, NIH, 1983-1987.
Co-organizer, Banbury Conf. on the Ubiquitin System, Cold Spring Harbor Laboratory, NY, 1993.
Visiting Fellow, International Institute for Advanced Studies, Kyoto, Japan, 2001.
Member, Advisory Board, Encyclopedia of Mol. Cell Biology and Mol. Medicine, 2002-2005.
Member, Advisory Board, Gairdner Foundation, Canada, 2002-2006.
Member, Advisory Board, Massry Foundation, 2002-2005.
Member, Advisory Board, Pasarow Foundation, 2002-2012.
Member, O'Connor Advisory Committee, March of Dimes Foundation, 2007-2012.
Member, Breakthrough Prize Committee, 2014-present.

Honorary Memberships:
Fellow, American Academy of Arts and Sciences, 1987.
Member, U.S. National Academy of Sciences, 1995.
Fellow, American Academy of Microbiology, 2000.
Foreign Associate, European Molecular Biology Organization, 2001.
Member, American Philosophical Society, 2001.
Fellow, American Association for Advancement of Science, 2002.
Foreign Member, European Academy of Sciences (Academia Europaea), 2005.

Awards:

Merit Award, National Institutes of Health, 1998.
Novartis-Drew Award in Biomedical Science, Novartis, Inc. and Drew University, 1998.
Gairdner International Award, Gairdner Foundation, Canada, 1999.
(with A. Hershko)
Sloan Prize, General Motors Cancer Research Foundation, 2000.
(with A. Hershko)
Lasker Award in Basic Medical Research, Albert and Mary Lasker Foundation, 2000.
(with A. Hershko and A. Ciechanover)
Shubitz Prize in Cancer Research, University of Chicago, 2000.
Hoppe-Seyler Award, Society for Biochemistry and Molecular Biology, Germany, 2000.
Pasarow Award in Cancer Research, Pasarow Foundation, 2001.
Max Planck Award, Germany, 2001.
Merck Award, American Society for Biochemistry and Molecular Biology, 2001.
(with A. Hershko)
Wolf Prize in Medicine, Wolf Foundation, Israel, 2001.
(with A. Hershko)
Massry Prize, Massry Foundation, 2001.
(with A. Hershko)
Horwitz Prize, Columbia University, 2001.
(with A. Hershko)
Wilson Medal, American Society for Cell Biology, 2002.
(with A. Hershko)
Stein and Moore Award, Protein Society, 2005.
(with A. Hershko)
March of Dimes Prize in Developmental Biology, March of Dimes Foundation, 2006.
Griffuel Prize in Cancer Research, Association for Cancer Research, France, 2006.
Gagna and Van Heck Prize, National Foundation for Scientific Research, Belgium, 2006.
Weinstein Distinguished Award, American Association for Cancer Research, 2007.
Schleiden Medal, German Academy of Sciences (Leopoldina), 2007.
Gotham Prize in Cancer Research, Gotham Foundation, 2008.
Vilcek Prize in Biomedical Research, Vilcek Foundation, 2010.
BBVA Foundation Award in Biomedicine, BBVA Foundation, Spain, 2011.
Otto Warburg Prize, Society for Biochemistry and Molecular Biology, Germany, 2012.
King Faisal International Prize in Science, King Faisal Foundation, Saudi Arabia, 2012.
Breakthrough Prize in Life Sciences, Breakthrough Foundation, 2014.
Albany Prize in Medicine and Biomedical Research, Albany Medical Center, Albany, NY, 2014.
Grande Médaille, French Academy of Sciences, 2016.
Wieland Prize, Boehringer Ingelheim Foundation, Germany, 2017.

Selected Publications (1968-present)

(grouped by the fields; numbered chronologically)

Chromosome Structure and Gene Expression

1. Varshavsky, A. (1968) Regulation of synthesis of genetic repressors in bacteria. **Mol. Biol**. (Russia) 2, 13-20.
4. Ilyin, Y. V., Varshavsky, A., Mickelsaar, U. N. and Georgiev, G. P. (1971) Redistribution of proteins in mixtures of nucleoproteins, DNA and RNA. **Eur**. **J**. **Biochem**. 22, 235-245.
5. Varshavsky, A. and Georgiev, G. P. (1972) Clustered arrangement of histones F2a1 and F3 in chromosomal deoxyribonucleoproteins. **Biochim**. **Biophys**. **Acta** 281, 449-674.
9. Varshavsky, A. and Georgiev, G. P. (1973) Redistribution of histones during unfolding of chromosomal DNA. **Mol**. **Biol**. **Reports** 1, 143-148.
12. Varshavsky, A. and Ilyin, Y. V. (1974) Salt treatment of chromatin induces redistribution of histones. **Biochim**. **Biophys**. **Acta** 340, 207-217.
14. Ilyin, Y. V., Bayev, A. A. Jr., Zhuse, A. L. and Varshavsky, A. (1974) Histone-histone proximity in chromatin as revealed by imidoester crosslinking. **Mol**. **Biol**. **Reports** 1, 343-348.
17. Varshavsky, A. and Bakayev, V. V. (1975) Nu-bodies and free DNA in chromatin lacking histone H1. **Mol**. **Biol**. **Reports** 2, 209-217.
18. Varshavsky, A., Bakayev, V. V. and Georgiev, G. P. (1976) Heterogeneity of chromatin subunits *in vitro* and location of histone H1. **Nucl. Acids Res.** 3, 477-492.
23. Varshavsky, A., Bakayev, V. V., Chumackov, P. M. and Georgiev, G. P. (1976) Minichromosome of simian virus 40: presence of histone H1. **Nucl. Acids Res**. 3, 2101-2114.
27. Varshavsky, A. (1976) Structural and functional organization of eukaryotic chromosomes. **Biol**. **Zentralblatt** 95, 301-316.
30. Bakayev, V. V., Bakayeva, T. G. and Varshavsky, A. (1977) Nucleosomes and subnucleosomes: heterogeneity and composition. **Cell** 11, 619-630.
31. Varshavsky, A., Nedospasov, S. A., Bakayev, V. V., Bakayeva, T. G. and Georgiev, G. P. (1977) Histone-like proteins in the *E. coli* chromosome. **Nucl. Acids Res**. 4, 2725-2745.
33. Varshavsky, A., Bakayev, V. V., Nedospasov, S. A. and Georgiev, G. P. (1977) On the structure of eukaryotic, prokaryotic and viral chromatin. **Cold Spring Harbor Symp. Quant. Biol**. 42, 457-472.
37. Varshavsky, A., Sundin, O. and Bohn, M. (1978) SV40 viral minichromosome: preferential exposure of the origin of replication. **Nucl. Acids Res**. 5, 3469-3478.
38. Varshavsky, A., Sundin, O. and Bohn, M. (1979) A 400 bp region of SV40 viral DNA that includes the origin of replication is exposed in SV40 minichromosomes. **Cell** 16, 453-466.
39. Sundin, O. and Varshavsky, A. (1979) Staphylococcal nuclease makes a single nonrandom cut in the SV40 viral minichromosome. **J. Mol. Biol.** 132, 535-546.
45. Levinger, L. and Varshavsky, A. (1981) *Drosophila* heat shock proteins are associated with nuclease-resistant, high salt-resistant nuclear structures. **J. Cell Biol.** 90, 793-796.
50. Barsoum, J., Levinger, L. and Varshavsky, A. (1982) On the chromatin structure of the amplified, transcriptionally active gene for dihydrofolate reductase in mouse cells. **J**. **Biol**. **Chem**. 257, 5274-5282.

51. Levinger, L. and Varshavsky, A. (1982) Protein D1 preferentially binds AT-DNA and is a component of *Drosophila melanogaster* nucleosomes containing AT-rich satellite DNA. **Proc**. **Natl**. **Acad**. **Sci**. **USA** 79, 7152-7156.
54. Wu, K., Strauss, F. and Varshavsky, A. (1983) Nucleosome arrangement in green monkey alpha-satellite chromatin. **J. Mol. Biol.** 170, 93-117.
67. Barsoum, J. and Varshavsky, A. (1985) Preferential localization of variant nucleosomes near the 5'-end of the mouse dihydrofolate reductase gene. **J. Biol. Chem.** 260, 7688-7697.
73. Solomon, M. J., Strauss, F. and Varshavsky, A. (1986) A mammalian HMG protein recognizes a stretch of six AT base pairs in duplex DNA. **Proc**. **Natl**. **Acad**. **Sci**. **USA** 83, 1276-1289.
80. Peck, L. J., Millstein, L., Eversole-Cire, P., Gottesfeld, J. M. and Varshavsky, A. (1987) Transcriptionally inactive oocyte-type 5S RNA genes of *Xenopus laevis* are complexed with TFIIIA *in vitro*. **Mol**. **Cell**. **Biol**. 7, 3503-3510.
91. Winter, E. and Varshavsky, A. (1989) A DNA-binding protein that recognizes oligo dA-oligo dT tracts. **EMBO J**. 8, 1867-1877.

Chromosome Replication and Cohesion/Segregation

41. Sundin, O. and Varshavsky, A. (1980) Terminal stages of SV40 DNA replication proceed via multiply intertwined catenated dimers. **Cell** 21, 103-114.
46. Sundin, O. and Varshavsky, A. (1981) Arrest of segregation leads to accumulation of highly intertwined catenated dimers: dissection of the final stages of SV40 DNA replication. **Cell** 25, 659-669.
55. Varshavsky, A., Sundin, O., Özkaynak, E., Pan, R., Solomon, M. and Snapka, R. (1983) Final stages of SV40 DNA replication: multiply intertwined catenated dimers as SV40 segregation intermediates. In: **Mechanisms of DNA Replication and Recombination**, Liss, Inc., New York, pp. 463-494.
56. Varshavsky, A., Levinger, L., Sundin, O., Barsoum, J., Özkaynak, E., Swerdlow, P. and Finley, D. (1983) Cellular and SV40 chromatin: replication, segregation, and ubiquitination. **Cold Spring Harbor Symp. Quant. Biol.** 47, 511-528.
81. Solomon, M. J. and Varshavsky, A. (1987) A nuclease-hypersensitive region forms *de novo* after chromosome replication. **Mol**. **Cell**. **Biol**. 7, 3822-3825.

Gene Amplification, Multidrug Transporters, and Drug Resistance

43. Varshavsky, A. (1981) On the possibility of metabolic control of replicon "misfiring": relationship to emergence of malignant phenotypes in mammalian cell lineages. **Proc**. **Natl**. **Acad**. **Sci**. **USA** 78, 3673-3677.
44. Varshavsky, A. (1981) Phorbol ester dramatically increases incidence of methotrexate-resistant cells: possible mechanisms and relevance to tumor promotion. **Cell** 25, 561-572.
55. Barsoum, J. and Varshavsky, A. (1983) Mitogenic hormones and tumor promoters greatly increase the incidence of cells bearing amplified dihydrofolate reductase genes. **Proc**. **Natl**. **Acad**. **Sci**. **USA** 80, 5330-5334.
56. Varshavsky, A. (1983) Diadenosine 5', 5'",-P^1,P^4-tetraphosphate: a pleiotropically acting alarmone? **Cell** 34, 711-712.
58. Varshavsky, A. (1983) Do stalled replication forks synthesize a specific alarmone?

J. **Theoret**. **Biol**. 105, 707-714.

59. Snapka, R. and Varshavsky, A. (1983) Loss of unstably amplified dihydrofolate reductase genes from mouse cells is accelerated by hydroxyurea. **Proc**. **Natl**. **Acad**. **Sci**. **USA** 80, 7533-7537.
63. Roninson, I., Abelson, H. T., Housman, D. E., Howell, N. and Varshavsky, A. (1984) Amplification of specific DNA sequences correlates with multidrug resistance in Chinese hamster cells. **Nature** 30, 626-628.
71. Ciccarelli, R. B., Solomon, J. J., Varshavsky, A. and Lippard, S. J. (1985) *In vivo* effects of cis- and trans diaminedichloroplatinum (II) on SV40 chromosomes: differential repair, DNA-protein crosslinking, and inhibition of replication. **Biochemistry** 24, 7533-7540.
72. Gros, P., Croop, J., Roninson, I., Varshavsky, A. and Housman, D. E. (1986) Isolation and characterization of DNA sequences amplified in multidrug-resistant hamster cells. **Proc. Natl. Acad. Sci. USA** 83, 337-341.
93. McGrath, J. P. and Varshavsky, A. (1989) The yeast *STE6* gene encodes a homolog of the mammalian multidrug resistance P-glycoprotein. **Nature** 340, 400-404.

New Biochemical and Genetic Methods

16. Bakayev, V. V., Melnickov, A. A., Osicka, V. A. and Varshavsky, A. (1975) Isolation and characterization of chromatin subunits. **Nucl. Acids Res**. 2, 1401-1419. *(Low ionic strength electrophoretic technique for separation of DNA-protein complexes.)*
22. Varshavsky, A., Bakayev, V. V. and Georgiev, G. P. (1976) Heterogeneity of chromatin subunits and location of histone H1. **Nucl. Acids Res**. 3, 477-492. *(Fractionation of nucleosomes by low ionic strength electrophoresis, the forerunner of gel shift assay.)*
42. Levinger, L., Barsoum, J. and Varshavsky, A. (1981) Two-dimensional hybridization mapping of nucleosomes. **J**. **Mol**. **Biol**. 146, 287-304.
49. Boyce, F., Sundin, O., Barsoum, J. and Varshavsky, A. (1982) New way to isolate SV40 viral minichromosomes: use of a thiol-specific reagent. **J**. **Virol**. 42, 292-296.
64. Strauss, F. and Varshavsky, A. (1984) A protein binds to a satellite DNA repeat at three sites which would be brought into proximity by DNA folding in the nucleosome. **Cell** 37, 889-901. *(The first application of gel shift assay for detection of specific DNA-binding proteins in cell extracts.)*
69. Solomon, M. J. and Varshavsky, A. (1985) Formaldehyde-mediated DNA-protein crosslinking: a probe for *in vivo* chromatin structures. **Proc**. **Nat**. **Acad**. **Sci**. **USA** 82, 6470-6474.
74. Swerdlow, P. S., Finley, D. and Varshavsky, A. (1986) Enhancement of immunoblot sensitivity by heating of hydrated filters. **Analyt**. **Biochem**. 156, 147-153.
76. Snapka, R. M., Kwok, K., Bernard, J. A., Harling, O. and Varshavsky, A. (1986) Post-separation detection of nucleic acids and proteins by neutron activation. **Proc**. **Natl**. **Acad**. **Sci**. **USA** 83, 9320-9324.
82. Varshavsky, A. (1987) An electrophoretic assay for DNA-binding proteins. **Meth. Enzymol.** 151, 551-565.
83. Bartel, B. and Varshavsky, A. (1988) Hypersensitivity to heavy water: a new conditional phenotype. **Cell** 52, 935-941. *(A generally applicable alternative to temperature-sensitive conditional mutants.)*
86. Solomon, M. J., Larsen, P. L. and Varshavsky, A. (1988) Mapping protein-DNA interactions in vivo with formaldehyde. **Cell** 53, 937-947. *(The chromatin immunoprecipitation assay (later termed ChIP) for mapping DNA-bound proteins of interest at specific DNA*

sequences in chromosomes, through the in vivo crosslinking, DNA fragmentation, immunoprecipitation, and DNA hybridization.)

112. Dohmen, R. J., Wu, P. P. and Varshavsky, A. (1994) Heat-inducible degron: a method for constructing temperature-sensitive mutants. **Science** 263, 1273-1276. (*A temperature-sensitive derivative of a protein that retains its wild-type amino acid sequence.*)
113. Johnsson, N. and Varshavsky, A. (1994) Ubiquitin-assisted dissection of protein transport across membranes. **EMBO J.** 13, 2686-2698. *(A ubiquitin-based method for analyzing kinetic aspects of protein translocation across membranes in vivo*.)
115. Johnsson, N. and Varshavsky, A. (1994) Split ubiquitin as a sensor of protein interactions in vivo. **Proc. Natl. Acad. Sci. USA** 91, 10340-10344. (*Use of split mutant ubiquitin, a single-domain protein, for detecting protein interactions in living cells. The idea of split-protein assay (also called the protein complementation assay (PCA)) has been extended by other labs to a variety of split-protein reporters, including GFP and DHFR.*)
123. Lévy, F., Johnsson, N., Rümenapf, T. and Varshavsky, A. (1996) Using ubiquitin to follow the metabolic fate of a protein. **Proc. Natl. Acad. Sci. USA** 93, 4907-4912. *(A method for producing equimolar amounts of a reference and a test protein in vivo.)*
127. Johnson, N. and Varshavsky, A. (1997) Split ubiquitin: a sensor of protein interactions *in vivo*. In: **The Yeast Two-Hybrid System** (P. L. Bartel and S. Fields, eds.), pp. 316-332, Oxford University Press, N. Y.
137. Dünnwald, M., Varshavsky, A. and Johnsson, N. (1999) Detection of transient *in vivo* interactions between substrate and transporter during protein translocation into the endoplasmic reticulum. **Mol. Biol. Cell** 10, 329-344.
147. Varshavsky, A. (2000) Ubiquitin fusion technique and its descendants. **Meth. Enzymol.** 327, 578-593.
148. Turner, G. C. and Varshavsky, A. (2000) Detecting and measuring cotranslational protein degradation *in vivo*. **Science** 289, 2117-2120.
169. Dohmen, R. J. and Varshavsky, A. (2005) Heat-inducible degron and the making of conditional mutants. **Meth. Enzymol.** 399, 799-822.
170. Varshavsky, A. (2005) Ubiquitin fusion technique and related methods. **Meth. Enzymol.** 399, 777-799.
210. Piatkov, K. I., Graciet, E. and Varshavsky, A. (2013) Ubiquitin reference technique and its use in ubiquitin-lacking prokaryotes. **PLoS One** 8, e67952.
223. Oh, J. H., Chen, S. J. and Varshavsky, A. (2017) A reference-based protein degradation assay without global translation inhibitors. **J. Biol. Chem.** 292, 21457-21465.

Multitarget Designs

117. Varshavsky, A. (1995) Codominance and toxins: a path to drugs of nearly unlimited selectivity. **Proc. Natl. Acad. Sci. USA** 92, 3663-3667.
132. Varshavsky, A. (1998) Codominant interference, antieffectors, and multitarget drugs. **Proc. Natl. Acad. Sci. USA** 95, 2094-2099.

The Ubiquitin System and Regulated Protein Degradation

40. Levinger, L. and Varshavsky, A. (1980) Separation of nucleosomes containing and lacking ubiquitin-H2A semihistone. **Proc**. **Natl**. **Acad**. **Sci**. **USA** 77, 3244-3248.
48. Levinger, L. and Varshavsky, A. (1982) Selective arrangement of ubiquitinated and D1 protein

containing nucleosomes in the *Drosophila* genome. **Cell** 28, 375-386.
53. Swerdlow, P. and Varshavsky, A. (1983) Affinity of HMG17 for a nucleosome is not influenced by the presence of ubiquitin-H2A semihistone but depends on DNA fragment size. **Nucl**. **Acids**. **Res**. 11, 387-401.
61. Finley, D., Ciechanover, A. and Varshavsky, A. (1984) Thermolability of ubiquitin-activating enzyme from the mammalian cell cycle mutant ts85. **Cell** 37, 43-55.
62. Ciechanover, A., Finley, D. and Varshavsky, A. (1984) Ubiquitin dependence of selective protein degradation demonstrated in the mammalian cell cycle mutant ts85. **Cell** 37, 57-66.
66. Özkaynak, E., Finley, D. and Varshavsky, A. (1984) The yeast ubiquitin gene: head-to-tail repeats encoding a polyubiquitin precursor protein. **Nature** 312, 663-666.
70. Finley, D. and Varshavsky, A. (1985) The ubiquitin system: functions and mechanisms. **Trends Biochem**. **Sci.** 10, 343-346.
75. Bachmair, A., Finley, D. and Varshavsky, A. (1986) *In vivo* half-life of a protein is a function of its N-terminal residue. **Science** 234, 179-186.
77. Özkaynak, E., Finley, D., Solomon, M. J. and Varshavsky, A. (1987) The yeast ubiquitin genes: a family of natural gene fusions. **EMBO J**. 6:1429-1440.
78. Finley, D., Özkaynak, E. and Varshavsky, A. (1987) The yeast polyubiquitin gene is essential for resistance to high temperatures, starvation and other stresses. **Cell** 48:1035-1046.
79. Jentsch, S., McGrath, J. P. and Varshavsky, A. (1987) The yeast DNA repair gene *RAD6* encodes a ubiquitin-conjugating enzyme. **Nature** 329:131-134.
84. Finley, D., Özkaynak, E., Jentsch, S., McGrath, J. P., Bartel, B., Pazin, M., Snapka, R. M. and Varshavsky, A. Molecular genetics of the ubiquitin system. In: **Ubiquitin** (M. Rechsteiner, ed.), pp. 39-75, Plenum Press, N. Y.(1988).
85. Varshavsky, A., Bachmair, A., Finley, D., Wünning, I. and Gonda, D. The N-end rule of selective protein turnover: mechanistic aspects and functional implications. In: **Ubiquitin** (M. Rechsteiner, ed.), pp. 287-324, Plenum Press, N. Y. (1988).
87. Goebl, M. G., Yochem, J., Jentsch, S., McGrath, J. P., Varshavsky, A. and Byers, B. (1988) The yeast cell cycle gene *CDC34* encodes a ubiquitin-conjugating enzyme. **Science** 241:1331-1335.
88. Bachmair, A. and Varshavsky, A. (1989) The degradation signal in a short-lived protein. **Cell** 56, 1019-1032.
89. Chau, V., Tobias, J. W., Bachmair, A., Mariott, D., Ecker, D., Gonda, D. K., and Varshavsky, A. (1989) A multiubiquitin chain is confined to specific lysine in a targeted short-lived protein. **Science** 243, 1576-1583.
90. Finley, D., Bartel, B. and Varshavsky, A. (1989) The tails of ubiquitin precursors are ribosomal proteins whose fusion to ubiquitin facilitates ribosome biogenesis. **Nature** 338, 394-401.
92. Gonda, D. K., Bachmair, A., Wünning, I., Tobias, J. W., Lane, W. S. and Varshavsky, A. (1989) Universality and structure of the N-end rule. **J**. **Biol**. **Chem**. 264, 16700-16712.
94. Balzi, E., Choder, M., Chen, W., Varshavsky, A. and Goffeau, A. (1990) Cloning and functional analysis of the arginyl-tRNA-protein transferase gene *ATE1* of *Saccharomyces cerevisiae*. **J**. **Biol**. **Chem**. 265, 7464-7471.
95. Hochstrasser, M. and Varshavsky, A. (1990) *In vivo* degradation of a transcriptional regulator: the yeast α2 repressor. **Cell** 61, 697-708.
96. Johnson, E. S., Gonda, D. K. and Varshavsky, A. (1990) *Cis-trans* recognition and subunit-specific degradation of short-lived proteins. **Nature** 346, 287-291.
97. Bartel, B., Wünning, I. and Varshavsky, A. (1990) The recognition component of the N-end rule pathway. **EMBO J**. 9, 3179-3189.

98. Hochstrasser, M., Ellison, M. J., Chau, V. and Varshavsky, A. (1991) The short-lived MATalpha2 transcriptional regulator is ubiquitinated *in vivo*. **Proc. Nat. Acad. Sci. USA** 88, 4606-4610.
99. Baker, R. T. and Varshavsky, A. (1991) Inhibition of the N-end rule pathway in living cells. **Proc. Natl. Acad. Sci. USA** 88, 1090-1094.
100. Varshavsky, A. (1991) Naming a targeting signal. **Cell** 64, 13-15.
101. Tobias, J. W. and Varshavsky, A. (1991) Cloning and functional analysis of the ubiquitin-specific protease gene *UBP1* of *S. cerevisiae*. **J. Biol. Chem**. 266, 12021-12028.
102. Dohmen, R. J., Madura, K., Bartel, B. and Varshavsky, A. (1991) The N-end rule is mediated by the Ubc2 (Rad6) ubiquitin-conjugating enzyme. **Proc. Natl. Acad. Sci. USA** 88, 7351-7355.
103. McGrath, J. P., Jentsch, S. and Varshavsky, A. (1991) *UBA1*: an essential yeast gene encoding ubiquitin-activating enzyme. **EMBO J**. 10, 227-237.
104. Tobias, J. W., Shrader, T. E., Rocap, G. and Varshavsky, A. (1991) The N-end rule in bacteria. **Science** 254, 1374-1377.
105. Johnson, E. S., Bartel, B., Seufert, W. and Varshavsky, A. (1992) Ubiquitin as a degradation signal. **EMBO J**. 11, 497-505.
106. Ota, I. and Varshavsky, A. (1992) A gene encoding a putative tyrosine phosphatase suppresses lethality of an N-end rule-dependent mutant. **Proc. Natl. Acad. Sci. USA** 89, 2355-2359.
107. Baker, R. T., Tobias, J. W. and Varshavsky, A. (1992) Ubiquitin-specific proteases of *S. cerevisiae:* cloning of *UBP2* and *UBP3*, and functional analysis of the *UBP* gene family. **J. Biol. Chem.** 267, 23363-23375.
108. Varshavsky, A. (1992) The N-end rule. **Cell** 69, 725-735.
109. Shrader, T. E., Tobias, J. W. and Varshavsky, A. (1993) The N-end rule in *Escherichia coli*: cloning and analysis of the leucyl, phenylalanyl-tRNA-protein transferase gene *aat*. **J. Bact**. 175, 4364-4374.
110. Madura, K., Dohmen, R. J. and Varshavsky, A. (1993) N-recognin/Ubc2 interactions in the N-end rule pathway. **J. Biol. Chem.** 268, 12046-12054.
111. Ota, I. M. and Varshavsky, A. (1993) A yeast protein similar to bacterial two-component regulators. **Science** 262, 566-569.
114. Madura, K. and Varshavsky, A. (1994) Degradation of G-alpha by the N-end rule pathway. **Science** 265, 1454-1458.
116. Johnston, J. A., Johnson, E. S., Waller, P. and Varshavsky, A. (1995) Methotrexate inhibits proteolysis of dihydrofolate reductase by the N-end rule pathway. **J. Biol. Chem.** 270, 8172-8178.
118. Baker, R. T. and Varshavsky, A. (1995) N-terminal amidase: a new enzyme and component of a targeting complex in the N-end rule pathway. **J. Biol. Chem.** 270, 12065-12074.
119. Varshavsky, A. The world of ubiquitin. (1995) **Engineering & Science** 58, 26-36.
120. Johnson, E. S., Ma, P. C. M., Ota, I. M. and Varshavsky, A. (1995) A proteolytic pathway that recognizes ubiquitin as a degradation signal. **J. Biol. Chem**. 270, 17442-17456.
121. Dohmen, R. J., Stappen, R., McGrath, J. P., Forrová, H., Kolarov, J., Goffeau, A. and Varshavsky, A. (1995) An essential yeast gene encoding a homolog of ubiquitin-activating enzyme. **J. Biol. Chem**. 270, 18099-18109.
122. Varshavsky, A. (1996) The N-end rule. **Cold Spring Harbor Symp. Quant Biol**. 60, 461-478.
124. Ghislain, M., Dohmen, R. J., Lévy, F., and Varshavsky, A. (1996) Cdc48p interacts with Ufd3p, a WD-repeat protein required for ubiquitin-dependent proteolysis in

Saccharomyces cerevisiae. **EMBO J.** 15, 4884-4899.
125. Varshavsky, A. (1996) The N-end rule: functions, mysteries, uses. **Proc. Natl. Acad. Sci. USA** 93, 12142-12149.
126. Grigoryev, S., Stewart, A. E., Kwon, Y. T., Arfin, S. M., Bradshaw, R. A., Jenkins, N., Copeland, N. G. and Varshavsky, A. (1996) A mouse amidase specific for N-terminal asparagine: the gene, the enzyme, and their function in the N-end rule pathway. **J. Biol. Chem.** 271, 28521-28532.
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Patents

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